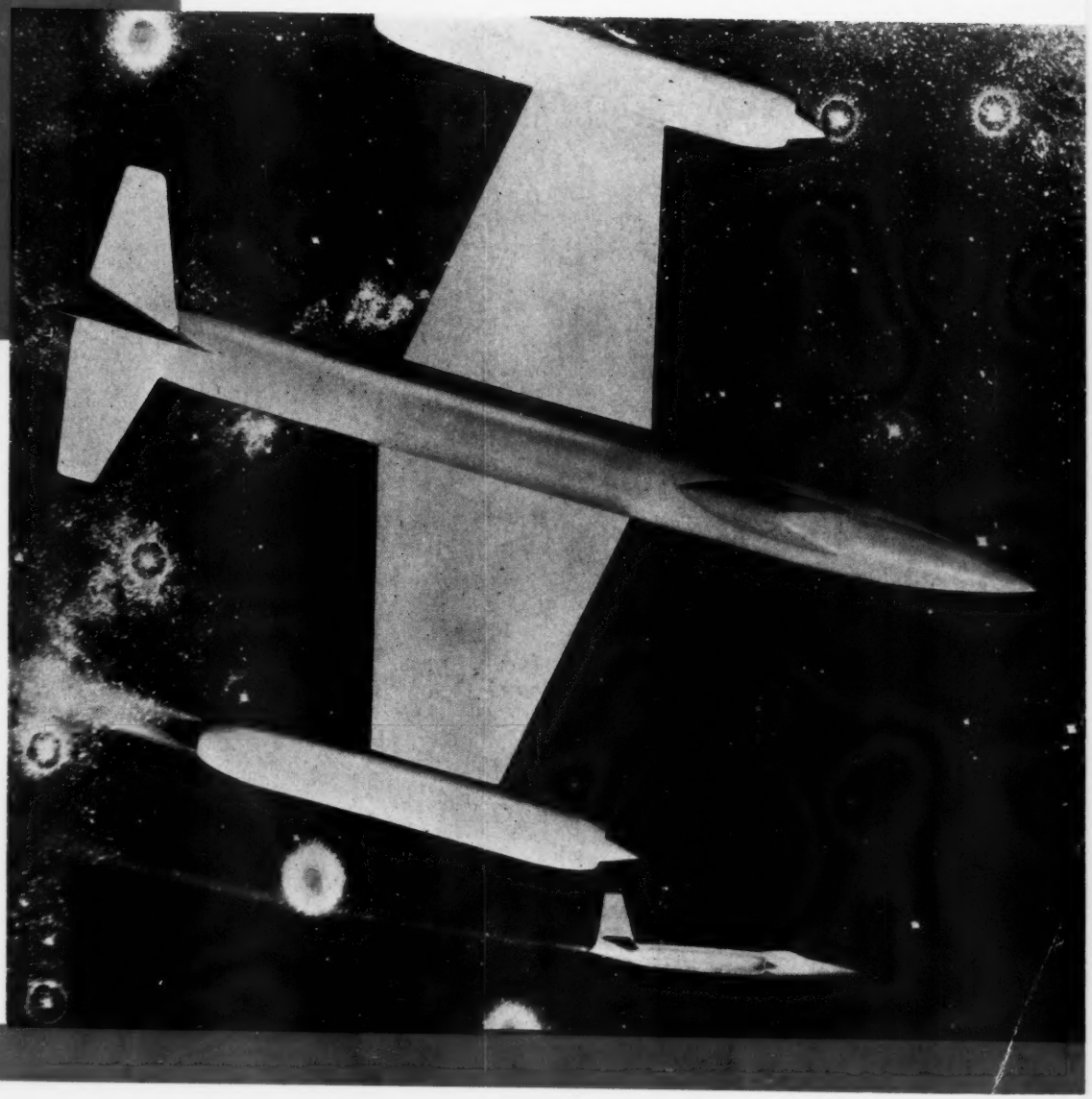
Aeronautical Engineering Review

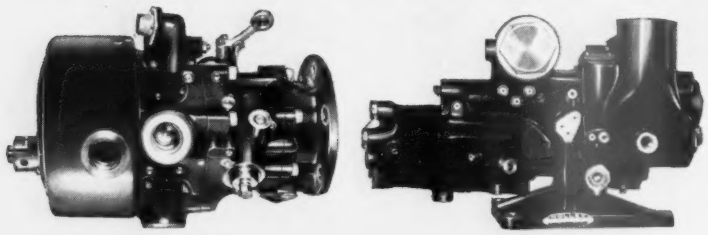


A Mid-Century Appraisal

December, 1953

Within Seconds After Warning . . .

the Lockheed Starfire is in the air and on its way to altitudes of more than 45,000 feet. Holley designed and manufactured the turbine fuel control and the afterburner fuel control used on the F-94C's Pratt & Whitney Aircraft J-48 Jet Engine.



HOLLEY
Carburetor Co.

DETROIT 4, MICHIGAN

LEADER IN THE DESIGN, DEVELOPMENT AND MANUFACTURE OF AVIATION FUEL METERING DEVICES.

Courtesy of Westinghouse Electric Corporation

Cover—This month's cover picture was photographically created by use of authentic NACA test models, combined with a natural astral scene photographed through the telescope at Warner & Swasey Observatory of Case Institute of Technology.

Editor
Welman A. Shrader

Managing Editor
Berneice H. Jarck

Assistant Editor
Rita J. Turino

Reviews Editor
F. J. Harsaghy, Jr.

News Editor
Beverly A. Dodge

Book Reviews Editor
John J. Glennon

Technical Advisers
Hugh L. Dryden
Robert R. Dexter
S. Paul Johnston

Advertising Manager
Joseph P. Ryan

Business Manager
Hugh C. Judge

Adv. Production Mgr.
R. N. Lipner

Western Office
7660 Beverly Blvd., Los Angeles 36, Calif.

SUBSCRIPTION RATES

Aeronautical Engineering Review: United States and possessions, 1 year, $3.00; single copies, $0.50. Foreign countries including Canada (American Currency Rates), 1 year, $3.50; single copies, $0.50.

Entered as second-class matter at the Post Office, Easton, Pa., April 29, 1942. Acceptance for mailing at a Special Rate of Postage as provided for in the Act of August 24, 1912.

Publication Office: 20th & Northampton Streets, Easton, Pa.

Editorial Office: 2 East 64th Street, New York 21, N.Y. Notices of change of address should be sent to the Institute at least 30 days prior to actual change of address.

Statements and opinions expressed in the Aeronautical Engineering Review are to be understood as individual expressions and not those of the Institute.

Copyright, 1953, by the Institute of the Aeronautical Sciences, Inc.

AERONAUTICAL ENGINEERING REVIEW

Vol. 12 **DECEMBER, 1953** **No. 12**

Contents

IAS News Notes 33
IAS News 35
Editorial 38

Articles

Why 1903? . . . . . J. C. Hunsaker 40
Design of Military Aircraft . . . J. H. Kindelberger 42
Evolution of Naval Aircraft, 1911–1954 . . . . . Rear Adm. Lawrence B. Richardson, USN (Ret.) 50
Design Trends—Transport . . . . A. E. Raymond 60
Design Trends in 50 Years—Civil Aviation Other Than Transport . . . . . T. P. Wright 74
Design Trends—Guided Missiles. Clark B. Millikan 82
Aerodynamics—Theory, Experiment, Application . . . . . Hugh L. Dryden 88
Structures—Theory, Materials, Methods. . . . . Hall L. Hibbard 96
A Slipstream View of Aircraft Propulsion, 1903–1953 . . . . . Frank W. Caldwell 108
Instruments and Control of Flight . . . . . Preston R. Bassett 118
The Institute's Corporate Member Family. 134

Reviews

Aeronautical Reviews 287
Books 305
New Products and Product Literature 319–322

Special IAS Publications 73
IAS Preprints. 268
Personnel Opportunities 307
Sherman M. Fairchild Publication Fund Papers . . 309
Index to Volume 12 310
Index to Advertisers. 316

Published Monthly by the Institute of the Aeronautical Sciences, Inc.

Proved... for Aviation's Higher Speeds

J-M Thermal Insulations

J-M Thermoflex* Blankets—used as standard protection on many Air Force and Navy jet aircraft, to insulate tail pipes, engine cones, afterburners, aft-frames and shaft housings. Also available in special preformed shapes for many other applications. These flexible blankets are made by Johns-Manville from a highly stable refractory fiber felt sealed between sheets of corrosion-resistant metal foils.

*Registered Johns-Manville Trade Mark.

New and improved products are constantly being developed in the Johns-Manville Research Center—world's largest insulation and packing laboratory. Here J-M Engineers and Scientists cooperate with leaders in the Aviation Industry to help solve their toughest problems and create products which will keep pace with aviation requirements.

As the aviation industry observes the golden anniversary of powered flight, Johns-Manville marks its 95th year of service to industry.

Johns-Manville is proud of the part its products have played in aircraft development . . . thermal insulation for protection against ex-

Johns-Manville

I.A.S. News Notes

December 1953

THE 1954 ANNUAL SUMMER MEETING

The 1954 Annual Summer Meeting of the Institute of the Aeronautical Sciences, now being planned by the Summer Meeting Subcommittee of the Los Angeles Section's Program Committee, will be held during the month of July. Sessions on the following subjects have been scheduled: Accessory Design Problems, Aerodynamics, Electronics and Aircraft Electrical Systems, Helicopters and Convertaplanes, Human Problems of Flight, Structures and Aeroelasticity, and Mechanical Problems of Flight.

It is requested that those persons interested in presenting papers at this meeting please forward abstracts and outlines of the proposed papers to: Program Chairman, Institute of the Aeronautical Sciences, 7660 Beverly Boulevard, Los Angeles 36, Calif. In order that the papers may be considered for presentation at the Summer Meeting, abstracts and outlines must be in the hands of the Program Chairman by January 15, 1954.

* * * * * * * *

BREWER AND WRIGHT TROPHIES TO BE PRESENTED

At the Wright Memorial Day Dinner to be given on December 17 by the Aero Club of Washington, President Dwight D. Eisenhower will present the Frank G. Brewer Trophy for 1953 to Dr. Leslie A. Bryan, MIAS, and the 1953 Wright Brothers Memorial Trophy to The Honorable Carl Hinshaw, MIAS.

Dr. Bryan, Director of the University of Illinois' Institute of Aviation, was cited for his many contributions to the development of aviation education in the United States.

Mr. Hinshaw, Member of Congress, U. S. House of Representatives, was selected as the recipient of the Wright Trophy because it was felt that his many comments and speeches on the floor of the House have contributed greatly to a better understanding by both the Government and the public of the problems of aviation.

* * * * * * * *

NECROLOGY

Harry R. Schmidt, Engineering Assistant, McDonnell Aircraft Corporation, on September 12.

John R. Stiles, Liaison Engineer, Rohr Aircraft Corporation, on October 22.

* * * * * * * *

NATIONAL MEETINGS CALENDAR

Dec. 17 — Seventeenth Wright Brothers Lecture, U.S. Chamber of Commerce Building Auditorium, Washington, D.C. Glenn L. Martin, Lecturer.

Jan. 25-29 — Twenty-Second Annual Meeting and Honors Night Dinner, Hotel Astor, New York.

* * * * * * * * * * * *

CALENDAR OF SECTION MEETINGS

Dec. 2 -- Philadelphia Section: Engineers Club, Dinner, 7:00 p.m.; Meeting, 8:00 p.m. Speaker, Dr. J. D. Hardy, Research Director, Aero-Medical Acceleration Laboratory, Johnsville, Pa., and Professor of Physiology, University of Pennsylvania. Subject not known at press time.

Dec. 2 -- Toronto Section: Mechanical Building, University of Toronto. Meeting, 8:15 p.m. "Problems Connected with Supersonic Flight" by Dr. H. H. Kurzweg, Chief, Aeroballistic Research Department, Naval Ordnance Laboratory, White Oak, Md.

Dec. 3 -- San Diego Section: IAS Building. Technical Meeting, 7:45 p.m. "Applications of the Interferometer to Aerodynamics" by Arnold Ritter, Consolidated Vultee Aircraft Corporation.

Dec. 10 -- New York Section: Tentatively scheduled for Engineering Society Building. Symposium on "Air Mapping Techniques" with Bruce Eaton as Monitor. Time of meeting not known at press time.

Dec. 10 -- San Diego Section: IAS Building, Dinner meeting, 7:00 p.m. "The Engineering Development of the Wright Brothers Airplane" by R. B. Johnston, The RAND Corporation.

Dec. 10 -- San Francisco Section: Ramor Oaks, Atherton, Calif. Social, 6:30 p.m.; Dinner, 7:00 p.m.; and Meeting, 8:00 p.m. "Rarefield Gas Dynamics" by Dr. Samuel Schaaf, University of California, Berkeley.

Dec. 15 -- Dayton Section: Reception, 6:30 p.m.; Dinner, 7:00 p.m., and Meeting, 8:00 p.m. Location, speaker, and subject not known at press time.

Dec. 17 -- Chicago Section: Sheraton Hotel, Meeting, 7:00 p.m. Section's contribution to the celebration of the Fiftieth Anniversary of Powered Flight, with Ralph S. Damon, President, Trans World Airlines, Inc., as speaker.

Jan. 13 -- St. Louis Section: Location, time, and speaker not known at press time. Subject, Flight Safety.

* * * * * * * * * * * *

IAS News

A Record of People and Events of Interest to Institute Members

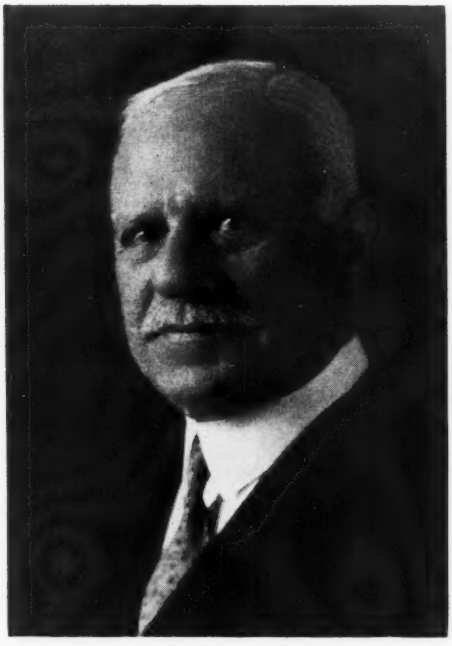
1953 Guggenheim Medal Awarded to Charles A. Lindbergh

Presentation to Be Made at IAS Honors Night Dinner January 25. Recipient Will Also Be Principal Speaker at Dinner

THE SELECTION of Charles Augustus Lindbergh as the recipient of the Daniel Guggenheim Award for 1953 has been announced jointly by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the Institute of the Aeronautical Sciences. Chairman of this year's Board of Award was Dr. T. P. Wright, Vice-President—Research, Cornell University. John R. Arms, Secretary of the United Engineering Trustees, is permanent Secretary of the Guggenheim Medal Board of Award. The award will be presented to the recipient by Harry Guggenheim at the IAS Honors Night Dinner to be held on January 25, 1954, at the Hotel Astor in New York.

Lindbergh was selected as this year's medalist "for pioneering achievements in flight and air navigation." His achievements have extended over a quarter of a century. His solo nonstop transatlantic flight from New York to Paris on May 20–21, 1927, touched off a chain of events that have changed the course of history. Since that epic flight, he has been active in mapping out domestic and overseas routes for overseas air lines, has made extensive contributions to the American aircraft manufacturing industry, and during and subsequent to World War II has served on numerous technical missions as an Adviser to the U.S. Air Force and U.S. Navy.

The Daniel Guggenheim Medal, which memorializes the late Mr. Guggenheim's great interest in aeronautics, was created as an international award to honor those persons who have made notable achievements in the advancement of aeronautics. It was provided for by a gift made in 1928 by the Daniel Guggenheim Fund for the Promotion of Aeronautics.



Daniel Guggenheim
in whose memory the Guggenheim Medal was initiated.

The first recipient of this annual award was the late Orville Wright, who was selected as the winner for 1929 "for design and construction, with his brother now deceased, of the first successful engine-propelled airplane." Subsequent medal winners have been Ludwig Prandtl, Frederick W. Lanchester, Juan de la Cierva, Jerome C. Hunsaker, William E. Boeing, William F. Durand, George W. Lewis, Hugo Eckener, Sir Roy Fedden, Donald W. Douglas, Glenn L. Martin, Juan T. Trippe, James H. Doolittle, Edmund T. Allen, Lawrence D. Bell, Theodore P. Wright, Sir Frank Whittle, Lester D. Gardner, Leroy R. Grumman, Edward P. Warner, Hugh L. Dryden, Igor I. Sikorsky, and Sir Geoffrey de Havilland.

Charles Lindbergh, who is an IAS Fellow and Founder Member, will be the Guest of Honor and Principal Speaker at the 1954 Honors Night Dinner.

Heraclio Alfaro, Associate Fellow and Founder Member of the IAS, a native and resident of Vitoria, Alava, Spain, who is well known in the U.S.A., Spain, and other countries for his work as an aircraft and engine designer, was recently honored at Vitoria by his compatriots with a flying meet and banquet. In the above picture, Col. José Juste, President, Real Aero Club of Madrid, is shown as he pins on Mr. Alfaro's lapel an emblem of the homage accorded to him as Spain's first airplane constructor and Vitoria's first pilot. Watching the proceedings from the right is Martin Ballesteros, Civil Governor of Alava. Mr. Alfaro is now Consultant, Heraclio Fournier S.A., Spain.

University of Michigan Names Department Head and Establishes New Professorship

At the September meeting of the University of Michigan's Board of Regents, Wilbur C. Nelson, AFIAS, Professor of Aeronautical Engineering, was named Chairman of the Department of Aeronautical Engineering, College of Engineering, University of Michigan. He succeeds Emerson W. Conlon, FIAS, who resigned from this position on July 1 to join Fairchild Engine and Airplane Corporation's Engine Division.

At the same meeting, Arnold M. Kuethe, FIAS, Senior Member of the University's Aeronautical Engineering Staff, was appointed to a new professorship of aerodynamics. This new professorship was established as a memorial to Felix Pawlowski, IAS Fellow and Founder Member, who directed the first program leading to a degree in aeronautical engineering at the University of Michigan in 1915. Professor Pawlowski retired from the Michigan faculty in 1946 as Professor Emeritus of Aeronautical Engineering and shortly thereafter moved to France where he died on February 17, 1951.

News of Members

▸ **Arthur Fage** (F), retired earlier this year as Superintendent, Aerodynamics Division, National Physical Laboratory, Great Britain, and was succeeded in this post by Dr. W. P. Jones. Mr. Fage joined the Laboratory's Aeronautical Division 41 years ago after studying at the Royal College of Science. He was awarded the C.B.E. in the recent Coronation Honours List in recognition of his services to aeronautics.

▸ **Dr. Richard Gilman Folsom** (AF) was recently appointed Director of the University of Michigan's Engineering Research Institute. The announcement of this appointment was made on September 1 by the President and Regents of the University of Michigan.

▸ **William Francis Gibbs** (AF), President, Gibbs & Cox, Inc., was awarded the Franklin Medal, the highest honor given by The Franklin Institute. The presentation was made at The Franklin Institute's Medal Day ceremonies on October 21. The citation accompanying the award read: "Because he has labored successfully for forty years to bring the best of engineering and architecture into shipbuilding, culminating in the construction of the recordbreaking S.S. 'United States.' "

▸ **Robert E. Gorton** (M), Development Engineer, Pratt & Whitney Aircraft Division, United Aircraft Corporation, was one of two instrument engineers to win the Manly Memorial Award of the Society of Automotive Engineers. The Manly Award was presented on October 2 to Mr. Gorton and Bruce E. Miller, also with Pratt & Whitney, for their paper on "Instrumentation for Aircraft Gas Turbine Development," which they presented at the January, 1952, SAE Annual Meeting.

▸ **Dr. R. Paul Harrington** (AF), Head, Department of Aeronautical Engineering, Rensselaer Polytechnic Institute, is conducting a research program to devise a method by which the origin of turbulence in fluid flow, either in pipes or channels or on free surfaces, may be determined experimentally. This method will be used ultimately to substantiate or disprove certain theories of the mechanism of turbulence in shearing flows. The program, the present phase of which is scheduled for completion this coming May 1, is being carried out for the Office of Scientific Research, Research, and Development Command, USAF.

▸ **Jerome Lederer** (F), Managing Director, Flight Safety Foundation, Inc., was given the Arthur Williams Award, one of the major honors in the field of safety. This presentation to Mr. Lederer marks the first time that the award has been given solely for achievement in aviation safety.

▸ **Joseph G. Logan** (M), now on sabbatical leave from Cornell Aeronautical Laboratory, Inc., is studying at the University of Buffalo for his Doctorate in Physics. Mr. Logan has

(*Continued on page 270*)

George J. Bindewald, AMIAS, has been promoted to General Sales Manager, Instrument Division, Thomas A. Edison, Inc. Formerly Aeronautical Sales and Service Manager of the Instrument Division, Mr. Bindewald is now responsible for selling and servicing all products of the division and coordinating the activities of the manufacturer's representatives in the general industrial field.

Necrology

Roland Belisle

The death of Roland Belisle, Loftsman, Canadair, Ltd., as a result of cancer was recently reported. The date was not given.

Mr. Belisle was born on July 19, 1906, in St. Gabriel de Brandon in the Province of Quebec, Canada, about 60 miles north of Montreal. He attended secondary school in Montreal and during the 1921–1922 academic year was a student at Laval University. Later on, he took an aeronautical engineering course through the International Correspondence School.

He worked for the Canadian Car and Foundry Company, Ltd., from 1942 to 1947. In 1943, he began doing layouts, lofting, and aircraft design, and, within 2 years, he had become Chief Loftsman for the Burnelli Project. In 1947, he joined Fairchild Aircraft in Canada, doing general aircraft lofting, and in 1948 he went with Cancargo Aircraft Manufacturing Company, Ltd. He joined Canadair, Ltd., in 1949.

Capt. Phillip M. Clinton

Captain Phillip Morris Clinton, USAF, TMIAS, was killed on July 6 in a USAF C-45 in Sparta, Wis.

Captain Clinton was born in Santa Barbara, Calif., on November 10, 1921. He attended the Spartan College of Aeronautical Engineering, receiving his A.A. in A.E. degree in December of 1949. He went to work the next January as a Draftsman for Wilson Manufacturing Company. At the time of his death, he was a Student Officer in Graduate Aeronautical Engineering at the Air Force Institute of Technology, Wright-Patterson AFB, Ohio.

He is survived by his widow.

M. B. Crawford

Marion Browning Crawford, MIAS, Staff Engineer, United Air Lines, Inc., suffered a heart attack and died on September 7. Mr. Crawford was 49 years of age.

A native of Crawford, Colo., Mr. Crawford attended the University of Denver in 1922 and 1923. He spent another 2 years at Western State College and took special courses at the University of Washington.

Between 1926 and 1931, Mr. Crawford worked at American Eagle Aircraft Corporation as a Design Draftsman, at the Alexander Aircraft Company as a Design Engineer, and at Spartan Aircraft Company as a Project Engineer—Design. In 1931, he joined Boeing Airplane Company, where he worked as a Group Leader in charge of equipment. He left Boeing in 1940 to become Equipment Engineer with United Air Lines Transport Corporation.

He is survived by his widow.

James E. Madden

Word has been received that James E. Madden, Design Engineer, Rohr Aircraft Corporation, died on June 20.

Mr. Madden was born on March 6, 1904, in Chicago, Ill., where he attended the Crane Technical High School from 1913 to 1917 and the Crane Technical College from 1917 to 1919. At the Crane Technical College, he studied Mechanical Engineering. At a later date, he took various war indoctrination courses at the San Diego State College.

He joined Consolidated Vultee Aircraft Corporation in San Diego in December of 1940. Between then and September of 1949, he worked successively at the San Diego plant as an Engineering Draftsman "A," Materials Engineer, Armament Engineer, Group Engineer in Development Engineering, and Materials Engineer "A" and Engineering Checker "A" in Production Engineering. Transferred in 1949 to Convair's Fort Worth plant, he was first Engineering Checker "A" for Production Engineering and later Engineering Designer "B" on the B-36. In March of 1951, he left Convair to become associated with Rohr Aircraft as Engineering Designer "B" for Power Plants and Accessories.

He is survived by his widow.

John C. Marsh

John C. Marsh, MIAS, died suddenly on July 31 following an operation. Mr. Marsh had been with Eastern Rotorcraft Corporation since about 1948 as a Director and Factory Superintendent.

A native of Philadelphia, Pa., he completed high school in 1931 and the following year went to work for Pitcairn Aircraft, Inc. In 1936, he enlisted in the U.S. Navy and was placed in charge of the assembly and repair hangar at the Reserve Aviation Base in Philadelphia. At the completion of his 4-year tour in the Navy, he joined Firestone Aircraft (formerly G & A Aircraft, Inc.). During World War II, he took military leave and served with the Navy for 2 years. Receiving a medical discharge, he then returned to Firestone and, when he left there about 1948 to join Eastern Rotorcraft, he was Firestone's Flight Test Engineer and Supervisor of the Experimental Department.

Mr. Marsh is survived by a 13-year-old son, Richard, and an 11-year-old daughter, Jeanne.

James O. Seay

James O. Seay, TMIAS, Engineering Test Pilot for Douglas Aircraft Company, Inc., since 1951, was killed during the week of September 14 when the AD-5 that he was test flying crashed into Chesapeake Bay. At the time of the accident, he was working out of the Naval Air Test Center at Patuxent River, Md.

Born in Kansas City, Kan., on December 17, 1922, Mr. Seay was a student at the Kansas City Junior College from 1940 to 1942. He then entered the Armed Forces and during 3 years of World War II won three Distinguished Flying Crosses and 13 Air Medals. In 1946, he continued his interrupted education at the University of Kansas, from which he was graduated in June of 1949 with a B.S. degree in Aeronautical Engineering. In June of 1951, he was graduated from the U.S. Navy Test Pilot Training School, and, at the time of his death, he had completed most of the requirements leading to a Master's degree in A.E.

This accident in which Mr. Seay was killed was reportediy the first fatality in the Douglas test group since January 1, 1944, when an A-26 pilot was killed on the West Coast.

Rudolph D. Van Dyke, Jr.

Rudolph Daniel Van Dyke, Jr., was killed in an airplane crash last June. Mr. Van Dyke was an Aeronautical Research Pilot for NACA's Ames Aeronautical Laboratory.

A native of Berkeley, Calif., Mr. Van Dyke attended high school in Dayton, Ohio. He matriculated at the University of Michigan in 1936 and was graduated from there in June of 1940 with a B.S.E. degree in Aeronautical Engineering.

Mr. Van Dyke entered the U.S. Navy in July of 1940, becoming a Naval Aviator and Squadron Engineering Officer. He was discharged from the Navy in 1946 and joined United Air Lines, Inc., as a copilot. In April of 1947, he joined Ames Aeronautical Laboratory as an Engineering Test Pilot.

Editorial

They Looked into the Future

The number of descriptive terms and adjectives that have been applied to the Wrights in this 50th Anniversary year of their first flight is beyond counting. Every laborer in the literary vineyard has scratched and scrabbled the rich soil of language to the point of diminishing returns to produce new word combinations that properly characterize the peculiar talents and the extraordinary traits of the Brothers from Dayton.

For the purpose of introducing this issue of the REVIEW, we will belabor (but briefly) only one of the many possibilities.

Wilbur and Orville Wright were *visionaries*.

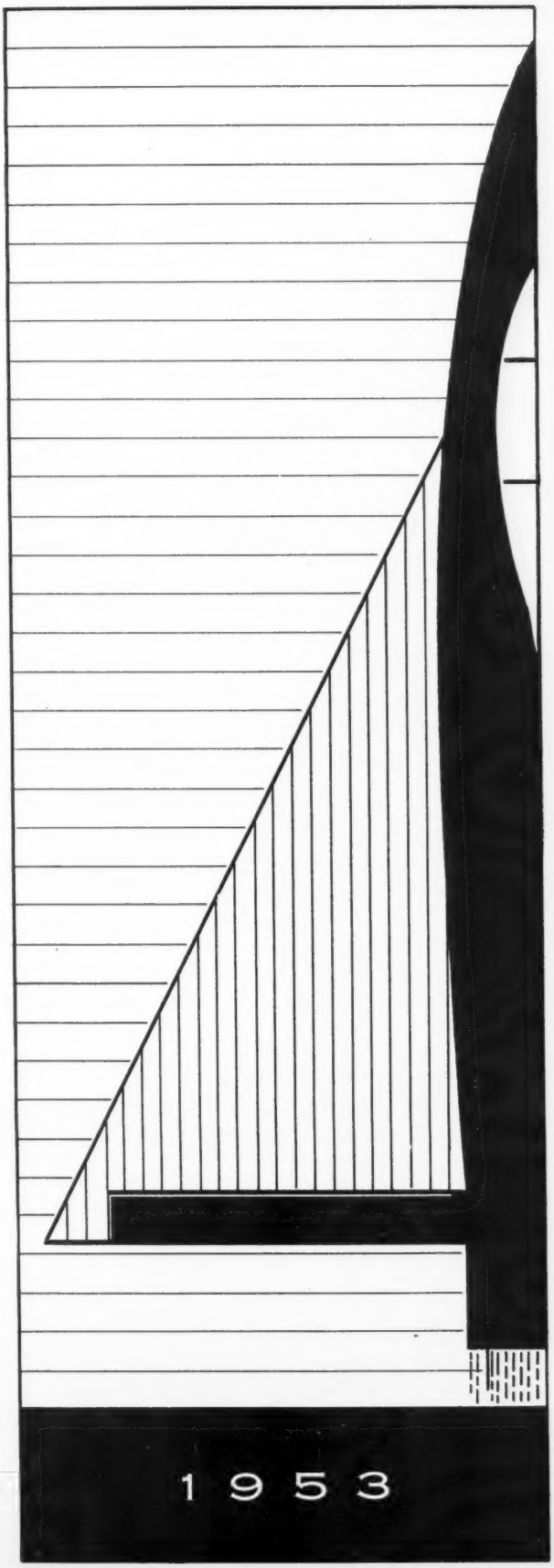
The implications of the term are not always good. The fuzzy-minded crackpot is sometimes included in that category. But no defense of the Wrights on that score need be offered. Their careers as intelligent, practical engineers are indelibly recorded on the pages of history. They were visionaries in the sense that they looked ahead. They projected their thoughts into the future to try to evaluate for themselves the impact of the thing that they had done.

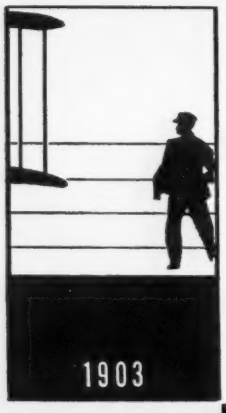
They were not, however, superhuman. Their vision, along with that of other men of science of the day, was limited. Man had not yet scaled the heights of the 1950's from which horizons appear almost limitless. It was considered a bit on the reckless side to speak (aloud) of speeds over 100

m.p.h. as late as 1910. It is certain that any thought that, before half a century had passed, a human pilot would travel over 1,200 m.p.h. to altitudes of over 80,000 ft. and return to tell the tale was utterly fantastic. That editorials such as this could be comfortably written 15,000 ft. in the air in a 300-m.p.h. four-engined airplane would have seemed to them equally ridiculous. The Wrights could only speculate and hope.

We are in a position at the mid-century mark to see much farther ahead. We can extrapolate from the well-marked trends of 50 years of experience. A considerable part of the total experience in the aeronautical sciences is wrapped up in the lives of the men who make up our Institute. The list of our Past-Presidents is itself a roster of names to whom aeronautics owes much. It was to this latter group that we turned in planning for this issue of the REVIEW. We asked certain of them who are specialists in particular fields of aeronautics to review for us the trends of the past 50 years and to project their ideas as far as could be done without transgression of security limits. Never before has such a distinguished group of authors been assembled between the covers of a magazine. All members of the IAS may take pride in the contributions that these fellow members of our organization have made to thus memorialize the 50th anniversary of powered flight.

S. P. J.





Why 1903?

By J. C. Hunsaker

Officer, USN, 1909–26: Instructor, M.I.T., 1912–16; In charge, aircraft design, USN, 1916–23; Asst. Naval Attaché, 1923–26. Asst. V.P., Bell Telephone Lab., 1926–28. V.P., Goodyear-Zeppelin, 1928–33. Head, Dept., M. & A. Engrg., M.I.T., 1933–48. Head, Dept., Aero. Engrg., 1948–51. Now Prof. (Emeritus).

MOST OF US NOW ALIVE were born since the dispatch of this brief telegram on December 17, 1903, from Kitty Hawk to Dayton: "Success: Four flights Thursday morning: Started from level with engine power alone: Average speed 31 miles: Longest 59 seconds: Inform Press: Home Christmas: Orville." It is very likely that the Wrights, father and sons, were not conscious of the world-shaking significance of the first proof that human flight was possible. The press did not think a hop of less than a minute worth reporting. However, with great persistence and true scientific intuition the Wright brothers developed a better flying machine from their Kitty Hawk experiments, and in 1908 demonstrated to an astonished world the first practical vehicle of the air.

It is still a matter for wonder that two young men in Dayton, without great technical or financial resources, were the first to fly. Of course, genius is unpredictable as to time or place, but genius at the wrong time and place creates nothing. A pair of brothers, like the Wrights, in 1853 would not have flown in the air.

It is no answer to the question "Why 1903?" to say that the first flight occurred in 1903 because the Wright brothers solved the riddle of control in 1902. Yet it is significant that in the late summer of 1902, they went to Kitty Hawk with their third glider, incorporating the changes found necessary from their flight experience with previous kites and gliders. In two months they made almost 1,000 glides and learned how to fly a straight course by the use of an interconnection between the vertical rudder and the wing warping controls.

The use of a vertical rudder for steering was old in the art, and the use of a horizontal rudder for longitudinal control had been disclosed in the patent issued jointly to Chanute and Mouillard in 1897. But the idea of wing warping for lateral control, coupled with the rudder to control the turn, was new.*

The Wright's principle of simultaneous control of attitude in the three axes or dimensions of space was the key to the riddle of flight which had completely escaped the nineteenth-century experimenters. Yet this 3-D concept was no more a novelty to those versed in mechanics than is the 3-D optical scheme now being applied to moving pictures. The Wrights' disclosure of simple means to control yaw, pitch, and roll was easily comprehended and was promptly adopted by others. It is a mystery to some present-day students that this now obvious solution did not occur to someone in the previous century.

Surely both Langley and Lilienthal, one an astronomer and the other a mechanical engineer, knew that the deflection of a surface remote from the center of

* Patent of May 22, 1906.

mass of an airplane would cause a moment of rotation. In fact, horizontal and vertical rudders were used on Langley models and on Lilienthal gliders to control pitch and yaw. Lilienthal counted on shifting his weight to control lateral attitude and Langley depended on dihedral wings.

Probably the simple and obvious solution was missed because Nature made the riddle difficult by curious and unfamiliar cross couplings. Yawing in a turn causes a roll or bank. Side slip causes both yawing and rolling. Warping down the low wing to increase its lift causes a desired rolling moment, but, at the same time, a drag increase to yaw the airplane away from its heading. Such cross coupling was discovered by the Wrights in their 1902 glider flights and led them to interconnect the wing warping and the rudder.

Recall that Orville and Wilbur Wright were the first men in the history of the world to fly. There was no one to teach them. They had to discover the principles and then to learn the art of flying by methodical and cautious experimenting with themselves aloft in gliders and kites. When Orville made his first powered flight in 1903 he already knew what he had to do. By 1908, both Wright brothers were skillful enough to take off, circle about, and land in still air. Their early airplanes were unstable and underpowered and very ready to stall. That is to say, their performance was so marginal that exact and delicate handling was necessary to avoid catastrophe.

Makers of riddles not only put in extraneous complications, such as the cross coupling in the airplane control problem, but also introduce misleading and false clues. Nature did this in the strange circumstance that an airplane, because of this very cross coupling, can apparently be controlled by using two of the three basic controls. It is not absolutely necessary to have wing warping or ailerons. With an adequate vertical rudder, an airplane with dihedral wings can be made to bank properly in a turn. This is a two-element control that works only fairly well. Langley and others thought it might be sufficient.

The most misleading phenomenon, however, was the excellent performance given by small free-flight models. From Penaud's toys of 1871 to Langley's large steam-engine-driven models, the literature before 1903 contains many accounts of "perfect" flights. One of Langley's machines was reported by Alexander Graham Bell (*Nature*, May 28, 1896) to have flown over the Potomac River "with remarkable steadiness in large curves of perhaps a hundred yards in diameter and continuously ascending, till its steam was exhausted,... when the machine settled down so softly and gently that it touched the water without the least shock. No one who was present could have failed to recognize that the practicability of mechanical flight had been demonstrated."

Note the qualifying phrase "mechanical flight." Dr. Bell may not have suspected that human flight was still many years away. Langley wrote at the time: "I have brought to a close the portion of the work which seems to be peculiarly mine...the demonstration of the practicability of mechanical flight...and for the next stage, which is the commercial and practical development of the idea, it is probable that the world may look to others."

Langley should have followed his first impulse and rested on his laurels, but he had caught the aviation fever. His "aerodrome" became the engrossing pursuit of the latter years of his life, entailing frustration, censure, and ultimate failure.

The scientific stature of this Smithsonian Secretary and pioneer experimenter with self-propelled flying models gave much needed respectability to flying machines. It is a tragedy that he is marked as a failure from his attempt to make a full-scale flying machine based on his models. Actually, he advanced the art by his scientific work and created, with Charles Manley, a light radial engine of outstanding characteristics.

Langley could never have learned to fly. He was too old, having been born in 1834, much too soon for the air age. He probably did not appreciate the cross coupling of yaw and roll and certainly did not realize the simplicity of the three-element control. He counted on steering an inherently stable airplane. His flying models proved only the stability part of his problem; no control was applied.

At about the time of Langley's model experiments F. W. Lanchester in England worked out the dynamics of such flying models and the theoretical conditions for their inherent stability. Perhaps fortunately, the Wrights never heard of Lanchester but, by some quality of their genius, realized that human flight would never be achieved by a passenger steering an inherently stable broomstick.

It is my guess that the Wrights, as bicycle builders, were well aware of the relation between the tilt of a bicycle rider and the course of his unstable vehicle. This is a cross coupling between roll and yaw very similar to that of an airplane. The Wrights proceeded to find out by experiment how to control a glider somewhat in the manner of a novice who learns to ride a bicycle without too much concern for dynamical complications.

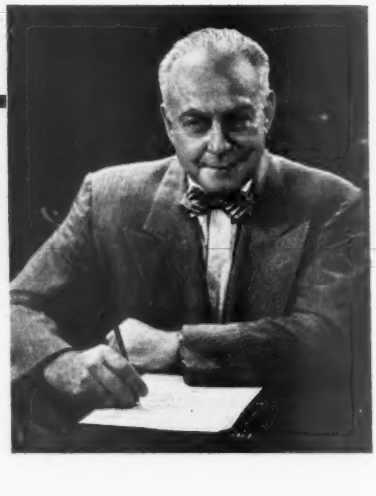
There was a further complication to flying that baffled the pioneers even after the Wrights had shown the way. This was the dangerous, and then quite unknown, limitation of longitudinal control to a narrow flight régime above the stalling speed and with available propeller thrust exceeding the drag. Early accounts of flying accidents usually attributed the dive into the ground resulting from a stall to an "air pocket."

I think I have said enough to show that the Wrights' simple solution was not easily discovered and applied. Why someone else had not thought of it is perhaps not a sensible question. Many people may have thought of it but were confused and misled by the difficulties attendant on application. The solution required the Wright brothers' persistence and logical processes of experiment and deduction and above all their dedica-

(*Continued on page 124*)

Design of Military Aircraft

By J. H. Kindelberger



Pilot—2nd Lt., WW I. Designer, The Glenn L. Martin Co. Vice Pres. and Chief Engineer, Douglas Aircraft Co., Inc., 1925–1934. Appointed Pres., North American Aviation, Inc., 1935. Chairman of the Board and Chief Executive Officer, North American, since 1948.

SINCE THE FIRST SIGNAL CORPS PILOT went aloft in a Wright biplane in 1908, it is estimated that about one billion man-hours have been spent in engineering the air-frame portion of U.S. military airplanes. My assignment is to discuss the design trends resulting from this engineering effort at the approximate ratio of one word per 200,000 engineering-hours.

Not being capable of such a miracle of brevity, I propose to examine in a general way the relationship between military requirements and design trends, giving a few examples where they appear pertinent. I hope to avoid a scholarly treatise on the birth of the military airplane, which would probably be boring to a readership comprising the midwives who assisted.

I like to think that aviation has progressed so rapidly at least partly because its challenge was so great, its problems so difficult. The Wright brothers invaded a tough neighborhood ruled by a bully named Gravity, and every airplane designer since has been so preoccupied with beating this bully and the other physical laws who are his brothers that there has been no energy whatsoever wasted on styles, fads, or ornamentation. Oddly enough, in thus eschewing the luxuries of style for a purely functional approach, the airplane designer has created style standards that, often quite unfunctionally, have been applied to automobiles and other products.

While all airplane design has of necessity followed purely functional lines, from the earliest attempts to get off the ground to our present efforts to master some of the lesser known phenomena of physics, the design of military airplanes has been influenced by an additional discipline—military requirements. Actually, this additional influence on the military plane designer has been far more compelling than the functional demands of flight or than, say, the influence upon the commercial plane designer to achieve a higher pay load, faster schedules, lower cost per passenger-mile, or greater passenger comfort. While the commercial designer, no less than the military designer, must work under the threatening guns of competition, the battleground for commercial competition is well defined by the cold facts of what the customer is willing and able to pay. The result is that commercial designs tend to cluster around an acceptable market standard of performance and general suitability.

But military requirements, by their nature, transcend all standards except the relative and highly elastic measure implied by the word "best." The object of war is to win, and the military designer can never know for sure that his design is good enough to win until the war is over. As a result, the designing of military airplanes involves a type of engineering necromancy that we might call "perfectioneering."

Before an examination of the factors affecting military design trends, a quick review of military aviation's brief but crowded past may be helpful as background.

The Early Years

In its earliest form, the airplane was not conspicuously suitable for military use. Marginally powered, it was capable of lifting very little useful load, military or otherwise, and its speed was so low as to offer little advantage over surface vehicles. In a very real sense, of course the early development of the airplane as a weapon was made possible largely by increases in the power-weight ratio of aeronautical engines, and only in comparatively recent years have such esoteric sciences as aerodynamics and structural design and thermodynamics come to the fore as major factors in our progress. Hence, the early saying that "you can fly a barn door if you put enough power on it"; we have since learned some serious aerodynamic limitations for a barn door in the transonic speed region.

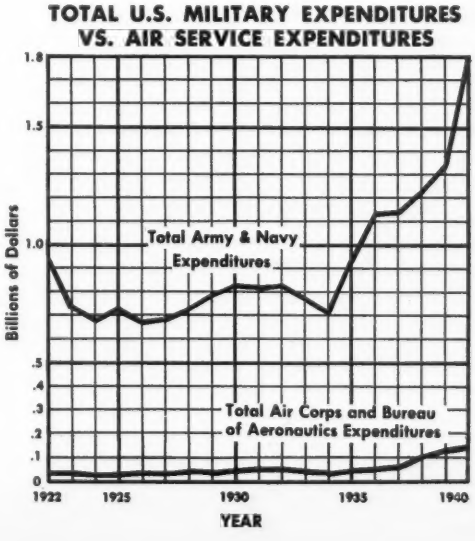
In view of the limited power available in the early years, it is not surprising that at the start of World War I, some 11 years after the Wright brothers' first flight, the airplane's military usefulness was conceived to be limited to observation work. Things happened fairly fast to change that view, however. Somebody got the idea of firing guns and dropping bombs from the air. Soon machine guns were being fitted to the aircraft in various ingenious ways, and the gentleman observers who previously had waved greetings to the enemy pilots while engaged in their scouting duties were shooting at each other in the first air warfare of history. Some bombing was attempted generally unsuccessful; fighters were put in the air to shoot down the bombers; some cargo was carried by air; and, of course, training aircraft were developed to prepare air crews for all this. The military accomplishments of the airplane when the armistice came had been inconclusive and even controversial, but the picture of the future was there for all to see. The reconnaissance plane, the fighter, the interceptor, the bomber, the cargo plane, and the trainer all existed in their earliest forms.

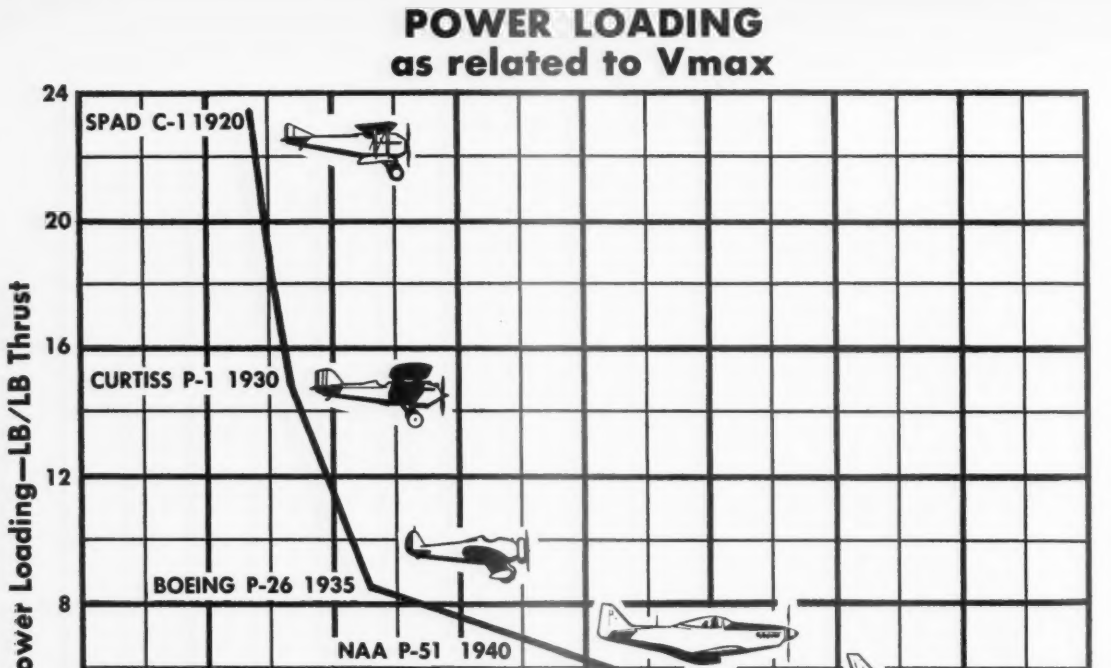
Between World Wars

Remarkable progress was made in military aviation between the two world wars despite the inadequacy of funds allocated to the air services. Between 1920 and 1940 the amounts expended in behalf of both the Air Corps and the Bureau of Aeronautics never reached as much as 10 per cent of total Army-Navy expenditures and, during most years, were below 5 per cent. The total of expenditures in behalf of the Army and Navy air services during the 20-year period was about $1.1 billion, which would keep our present military aviation program going for less than 3 weeks. Nevertheless, the art of aeronautical design moved soundly forward, and the technical innovations and improvements developed and applied in this period, many tried initially on military types, provided the basis for the air power of

America's first military airplane.

Curtiss JN-4D, first quantity-produced military airplane.





World War II. Roughly, in the order of their application, these important innovations included the radial air-cooled engine, improved airfoil sections, radial engine cowling, blind-flying instruments, wing flaps, retractable landing gear, the full cantilever wing, the controllable-pitch propeller, stressed-skin monocoque construction, and tricycle landing gear.

In addition to these general milestones in aeronautics, which had application to military and civil aviation alike, excellent progress was made in military equipment and techniques, although frequently the developments were not widely applied during this peacetime period. Practically all the aircraft ordnance, bombardment, and defensive equipment utilized in World War II had been tried at least experimentally prior to 1941. Nevertheless, we entered the war with generally inadequate military equipment on the aircraft in service and promptly began the frantic scaling up of armament and other combat equipment as soon as we learned what we were up against in a shooting war. Probably the previous failure to build effective fighting machines was as much due to our peaceful outlook as to the shortage of funds. Back in 1937, my company submitted to the Air Corps a bomber equipped with power-driven turrets. But we sold no bombers until the B-25, which in its initial configuration (designed in 1939–1940) carried a few manually operated 0.30 cal. guns. It later became the heaviest armed airplane of World War II.

World War II

As far as U.S. military aviation is concerned, the second world war may be characterized as a period of intensive design improvement and refinement rather than as a period of innovation. With tremendous production and correspondingly extensive service experience, the designers of military aircraft, engines, and aeronautical equipment were able to achieve a degree of functional perfection that may never again be equaled in aviation. The efficiency and reliability of such airframe, engine, and propeller combinations as the B-17 bomber and P-51 fighter were the products of intensive experience under all conditions, coupled with unprecedented engineering concentration.

While the bulk of U.S. aeronautical engineering effort during the war period was devoted to improving existing designs, some work was being done in the United States, and more elsewhere, on the innovations that have since revolutionized military aviation. These were in such areas as power-plant technology, transonic and supersonic aerodynamics, fire and flight control, and aircraft ordnance. The list of develop-

ment areas might also include nuclear science, for the atomic bomb certainly caused as many changes in aeronautical requirements as any new device before or since and added a new urgency to both offensive and defensive developments in military aviation.

Design Frontiers

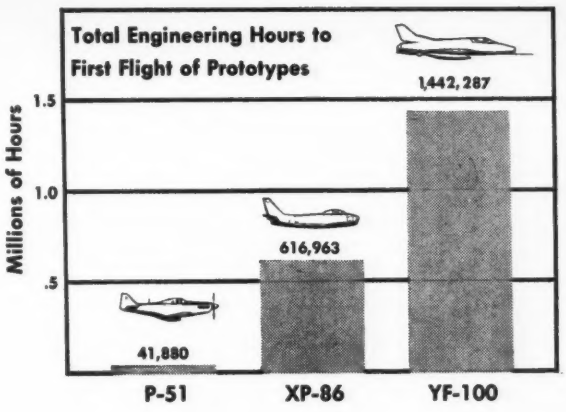
Looking back over the trials and tribulations of military aircraft design through the years, it is difficult to make any sweeping generalizations or neat summaries concerning design trends. Having been up to my elbows in the business for 35 of the 50 years, I can say from experience that the job looked tough at every step of the way, and we certainly weren't conscious of any orderly progression except that involved in beating our way out of each new set of problems that came along. Much of the time it was trial and error.

However, hindsight is a wonderfully facile thing, and with its aid one can assign some semblance of order to almost any process. For example, we can say that the design of military aircraft has been a process of working against successive barriers or limitations and of exploring and mastering various new frontiers. As I see it, these limitations can be summarized as follows for the past and the immediate future.

Power (1903–1945).—Prior to 1945, when various kinds of reaction engines became available for practical design use, military aircraft design trends were effectively limited by available power. Most of our progress resulted from additional increments of engine power and from various refinements of propeller and air frame to utilize engine power as efficiently as possible. After 1945, we had available, or in sight, most of the possible types of propulsion, and the range of power that could be drawn upon went far beyond immediate practical requirements for manned aircraft.

Materials and Structure (1920–1940).—Starting about 1920, when gradually increasing performance and weights demanded new structural strength, we passed through a period of experimentation with new materials and structural forms. While not a limitation in the same sense as power, the problem of structural design and materials was sufficiently important to consume an important part of our design effort. Out of this effort came the all-metal full-cantilever wing and the stressed-skin monocoque fuselage. The period saw great advances in alloying aluminum as an aircraft material, and new sheet-metal manufacturing methods made possible improved reinforced shell design. By the start of World War II, sufficient progress had been made in light alloys and sufficient experience had been gained in metal structures so that the problem was no longer critical, although we are still trying to whittle away every ounce of structure that we can because the rewards for that kind of effort in terms of performance are getting bigger every day.

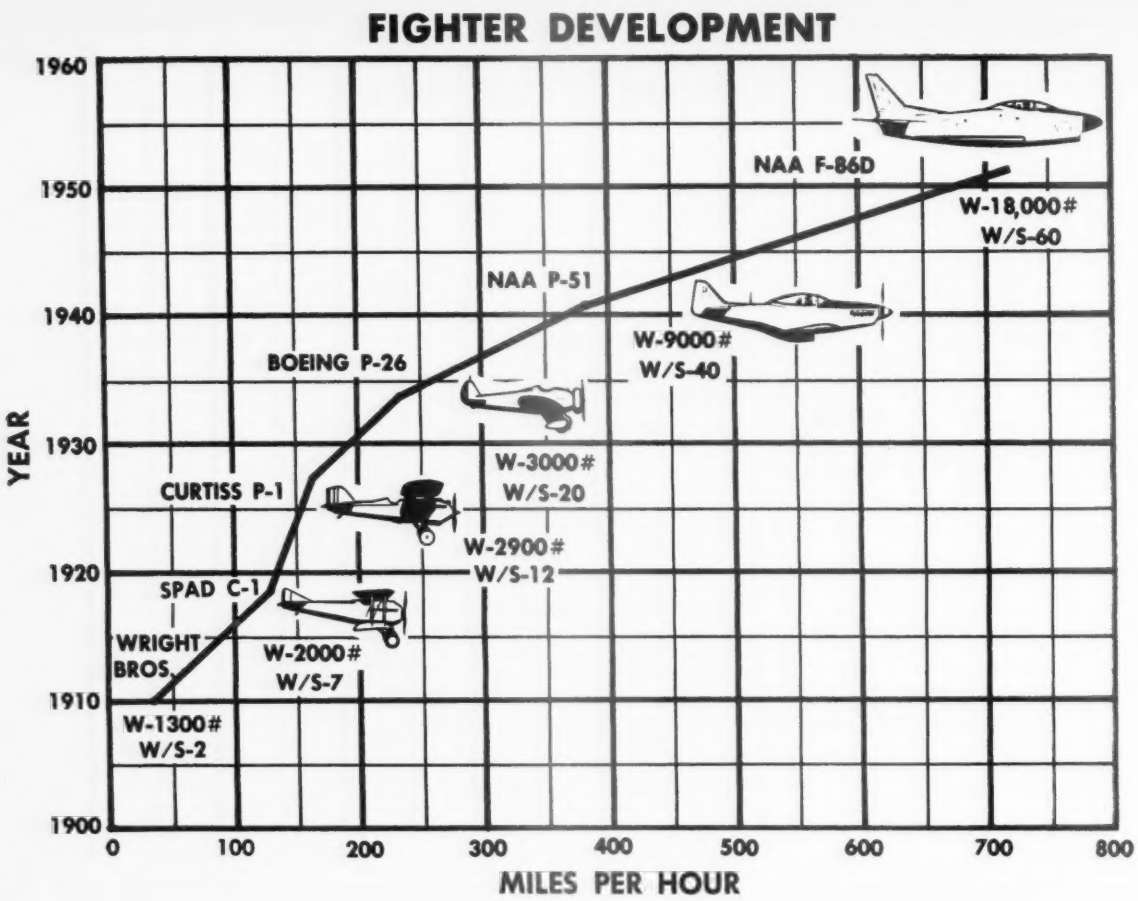
Aerodynamic Form and Control (1935–1950).—In the later stages of refinement of piston-engine combat aircraft, as sonic air velocities were encountered on portions of the airplane's surface, unpredicted phenomena of aerodynamics began to trouble designers. Compressibility effects, interferences, and various aspects of stability and control became serious design problems. These problems were compounded in the postwar years as performance gains accelerated. Aerodynamicists had to throw the book away and painfully learn a whole new set of transonic and supersonic principles. In developing the F-100 fighter, we spent 364,000 engineering man-hours in aerodynamic research before the first airplane flew; in contrast, the P-51 fighter, equally successful in its day, required less than 2 per cent of this effort in aerodynamic research. By 1950 we had learned how to design an airplane having reasonably satisfactory characteristics at velocities well beyond Mach 1, and a relatively less difficult period of refinement seemed to lie beyond the sonic frontier.



Accuracy and Reliability of Mission Gadgetry (1950–?).—Accuracy requirements, increasing as the square of performance advancements, forced us into a tremendous increase in gadgetry—ranging from fantastically complex radar installations down to small servomotors required to perform vital work at unprecedented speeds. Today, the whole machine's usefulness in performance of the mission depends upon this gadgetry, much of which is still in the early development stage, difficult to install correctly, hard to maintain in working order, and in many cases unreliable. Inevitably these problems will be solved as greater experience is gained, but today they are imposing a critical handicap at the early production and service test phases of the development cycle.

Thermal Effects (1955–?).—New designs now being projected run directly against the problem of thermal effects on structures and equipment. Whether this problem can best be solved by nibbling at each specific limitation as it confronts us, which we are now doing, or by a bold new innovation, it is perhaps too early to say. But it would appear at this time that, after 1955, we will have in operation aircraft that will be at the outposts of the thermal frontier as we see it today.

Physiological Limitations of Air Crews (1960–?).—On the basis of present and foreseeable power-plant developments and resulting performance capabilities, we may



soon be designing vehicles wherein compromised performance may be necessary because of the physiological limitations of operating personnel. Heat, cold, intolerably low pressure, harmful radiations, and acceleration are some of the conditions which may be critical with respect to the human body. Already we are close in our design thinking to the point where the air crew will be more of a penalty than an asset. We are already crossing the line in our guided missiles, which are simply pilotless aircraft designed to be expendable after one mission. The frontier of physiological limitations will mark the final and absolute separation of military and commercial design trends, since the military job can be done without human beings in the vehicle but nobody yet has thought of a way to transport passengers from New York to Paris in dematerialized form.

Out of the first 50 years of powered flight, two major world wars, and several lesser wars, have emerged certain reasonably well-defined combat airplane missions: (1) strategic bombardment of surface targets; (2) tactical support of surface forces; and (3) interception of air attacks. The list excludes such supporting functions as training, transport, and reconnaissance—each of which is important although subject usually to less rigorous requirements.

Within certain limitations, the designer's job with respect to each of these combat missions can be described as the best possible compromise of six objectives: (1) speed, (2) altitude, (3) range, (4) military load, (5) accuracy, and (6) economy. One interesting approach to the subject of military requirements and design trends is to consider how each of these objectives has fared through the years.

Speed

From the earliest days of power flight, speed increases have been the holy grail of the aeronautical engineering profession—the primary objective of aircraft design. At first it was a matter of securing enough forward motion to make the airfoil principle work. Before military aviation was very old, speed became the prime element of air superiority, and it has been so ever since. The faster the attacking aircraft can fly, the safer it is from ground or air defense. And naturally the defending aircraft wants to fly faster than the attacking aircraft so that it can shoot the attacker down.

There is no limit to the speed requirements of the military services, at least with regard to combat types. There is no "fast enough." Thus, when the jet engine made possible an overnight speed increment of more than 100 m.p.h., where previously our progress had been in small fractions of that value, there was no holding back. Rather there was intensive effort to develop even more powerful jet engines, and research to

reduce drag and to solve the aerodynamic stability and control problems inherent in the resulting new speed capabilities.

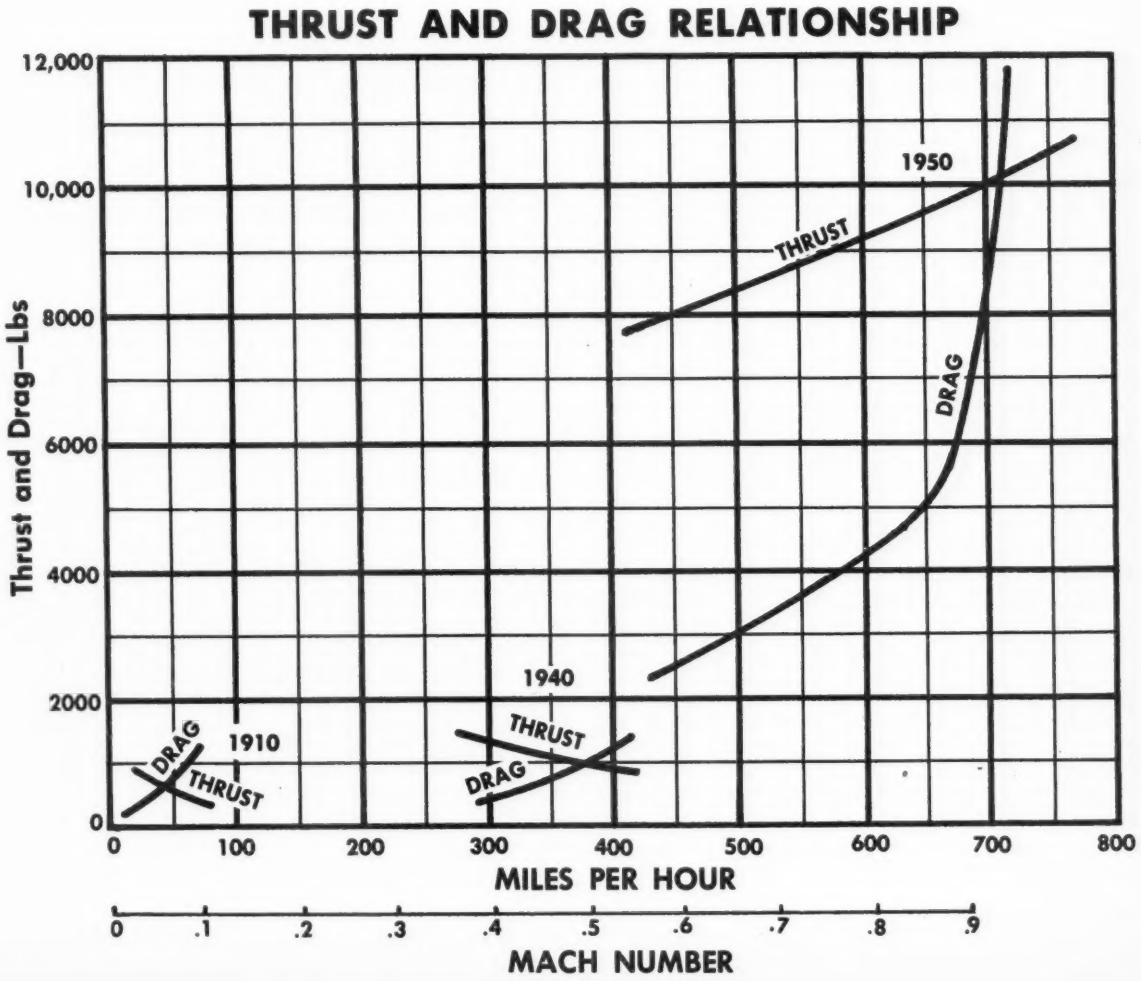
In air-frame design, which had been refined nearly to the ultimate of low drag for the 400-m.p.h. region, new trends were started involving radical changes in shape, control systems, equipment, and structures. Swept, low aspect and thickness ratio wings, power-actuated surface controls, buried antenna, and heavy-gage tapered sandwich structures were among the specific solutions to problems in these areas. But each solution brought new problems as near-sonic and transonic phenomena were explored in wind-tunnel and flight trials.

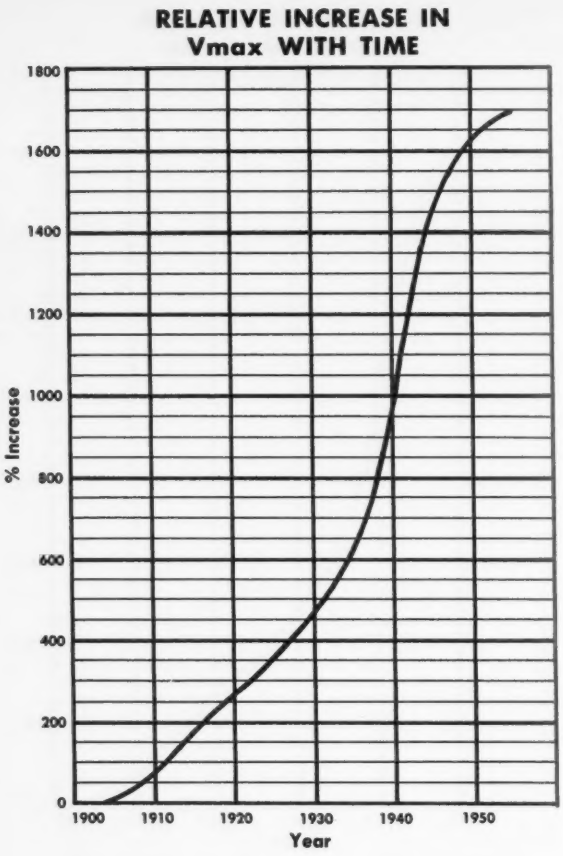
For example, the instability experienced with swept wings at near stalling speeds resulted in experiments with various solutions, including wing slats, wing fences, and altered horizontal tail position and wing aspect ratios. As is always the case, the problems seem relatively simple when the solutions have been found, but in the frantic period of exploration it often appears that the laws of physics are capriciously defying our best efforts.

Altitude

With piston-propeller aircraft, the objective of altitude, unlike the drive for speed, has certain built-in limitations. There is a "high enough" for almost every mission. For the bomber it is the altitude offering maximum safety and best fuel economy with satisfactory bombing accuracy. For the interceptor or fighter it is the altitude necessary to attack the bomber or the opposing fighter effectively. For the ground support airplane it is the altitude necessary for safety and effective delivery, often minimum terrain clearance. In each instance, design for more altitude than "high enough" could compromise some other element of performance needlessly.

In the early years, bomber altitude actually set the pace for all military aircraft altitude requirements. There was not much incentive to fly high, because the crude bombsights of the time made it difficult to hit anything even from low altitudes, and in any case the antiaircraft weapons were not especially effective. By the time of World War II, however, antiaircraft fire was getting a longer reach and deadly accuracy. Meanwhile, engine developments, including the turbo-





supercharger, had enabled us to fly higher, and the Norden computing bombsight had come along to give us an acceptable bombing accuracy at altitudes on the order of 25,000 ft.

With advent of the jet engine, altitude became a vital factor in cruise efficiency and therefore in range capability. Efficient cruise altitudes were suddenly boosted about 10,000 to 15,000 ft., and further increases awaited only jet-engine refinement. At the same time, in the atomic bomb we had a new weapon capable of destroying a large area, thus reducing the necessity for pinpoint accuracy. So all combat aircraft jumped into the thin air of 40,000 to 50,000 ft., presenting new survival problems to the air crews and a lot of tough headaches to the designers, including pressurization, low temperatures, escape provisions, and the necessity for elaborate search and fire-control gear to accomplish the mission under conditions of reduced maneuverability and a vastly expanded air battlespace.

The lag of military altitude requirements behind capability is illustrated by the fact that the world altitude record at the start of World War II was 56,000 ft., and 6 years later no combat airplane had been designed even to approach this altitude. In contrast, speed requirements have always pushed the upper limit of capability. Fighter aircraft have operated close to the world speed records since the beginning of military aviation, and military aircraft have actually established many of the official world speed records.

Range

Like altitude, the requirement for range tends to be restricted by other factors. The ideal, of course, is to have exactly enough range to fly from home base to the point of attack and get home safely. For an intercontinental bomber this may mean an operating radius of about 4,000 miles, while for a tactical aircraft it may be as little as a few hundred miles. Rather than design any surplus range into the aircraft, it is obviously desirable to use the latitude for greater speed, lighter weight, and other more essential characteristics.

Since any military airplane is most vulnerable through its base of operations, there is a natural inclination to want the base far enough away from enemy bases so that enemy aircraft cannot reach it, yet close enough so that the home team can reach enemy bases. Up to a point, this results in a constant effort to get just a little more range than the enemy has. The fellow with the longest sword gets stuck less frequently.

Aircraft range played a critical role in shaping the strategy and outcome of World War II. The island-hopping technique of winning back the Pacific was forced upon us by the necessity of keeping a friendly umbrella of aircraft over our fighting forces. In the European theater, the entire strategic bombing program at one point depended upon the ability to get longer range in our escort fighter aircraft. This was accomplished, to the amazement and chagrin of the German strategists, and the tide was turned in our favor. Generally speaking, no long-range fighter can match enemy interceptors over the target area because of the penalties it must incur to get the extra range. But, through extraordinary technical effort, it was done in the case of the P-51 Mustang vs. the best German fighters of 1944–1945 and again in the case of the F-86 Sabre vs. the Russian MIG-15 of 1951–1953.

Military Load

The tendency to increase military load is fairly well known. To the designer it often seems that the customer regards his nice clean airplane as a Christmas tree on which should be hung as many decorations and ornaments as possible. However bitter we may often feel about it, the tendency is certainly understandable in view of the fact that the function of the military airplane is to deliver destruction in one form or another to the enemy, and the more destruction that can be packed into one delivery the better. Partly because of this tendency to increase military load, the natural trend of any airplane design is toward increased weight.

From the standpoint of ordnance, the major developments have been the light machine gun, heavy machine gun, aircraft cannon, air-borne free-firing rocket, and air-borne guided rocket. In bombardment, the major developments have been the explosive bomb, the incendiary bomb, and the atom bomb. In each category there have been sharp improvements and refinements as experience has developed. The rate of fire of various forms of ordnance has climbed steadily, as have

the size and effectiveness of bombs. Comparison may be made of the first B-25 airplane, carrying four machine guns capable of delivering 5 lbs. of lead per sec., and the B-25J airplane of 4 years later, carrying 18 machine guns capable of delivering 24 lbs. of lead per sec. Equally impressive was the increase of bomb load in the heavy bombers, from the 1941 heavy bomber capable of carrying 4,000 lbs. to the 1945 very heavy bomber capable of carrying 20,000 lbs.

Development of aircraft rockets and the atomic bomb have made possible infinitely greater effectiveness with relatively small aircraft load. As these new weapons are improved and the method of delivering them refined, we can expect that the military load requirement will jump higher. The logistics of how many eggs it is wise to place in one basket and the requirement that the basket fly fast, high, and far are really the only practical limits to the demand for maximum military load.

Accuracy

Accuracy in delivery of the military load has become a critical problem only in recent years. Twenty years ago the design and installation of equipment necessary for accuracy was a negligible part of the total aircraft job, involving a few relatively simple navigation instruments and an elementary sighting device for gunnery or bombardment. Even during World War II we had not progressed very far in complexity, having added only radio navigation and a gyro stabilizing feature for the optical sights. But with the tremendous increases in speed, altitude, and range which began at the end of the war, infinitely more elaborate equipment was necessary to maintain logistically tolerable accuracy. Today, the design, construction, installation, and adjustment of this accuracy equipment generates in some instances more than one-third of the total airplane cost. Additionally, it has created serious space, weight, and cooling problems to the designer—in many instances resulting in the compromise of other design aspects. However, since the degree of accuracy attained in delivery of the military pay load is the most vital factor in determining the size of the force required to perform a given mission, we must accept any reasonable design penalty, and there is little probability that this emphasis will change.

Actually, the only practical limitation on accuracy requirements today is time. We must incorporate the most accurate equipment that can be developed in time to go into the airplane, and the extent to which we try to push back even that limitation is indicated by the fact that more than one airplane production program in recent years has been retarded through waiting for workable gadgetry of advanced types.

Economy

Although secondary to other objectives that must be attained for performance of the mission, economy is a very real factor in the formulation of aircraft requirements and in many design decisions. At the requirements level, sound judgment must be exercised in all phases of military aviation planning in order to accomplish necessary missions at the smallest cost in equipment, man power, and supplies. In wartime, the motivation for this emphasis on economy is the knowledge that efficient utilization of available resources can be the difference between defeat and victory. If the military planners should be inclined to forget the lesson in peacetime, they are promptly reminded of it, at least in our nation, by a highly articulate taxpaying public.

A modern all-weather fighter, the North American F-86D.

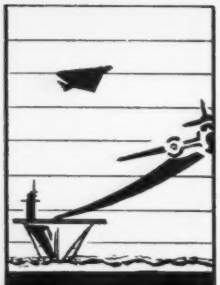
At the design level we are concerned with many phases of economy. We assist the services in conceiving the most economical weapon system to accomplish a given mission. In meeting the resulting requirements, we strive to design for economical production and minimum operating and maintenance cost. Our degree of success in these efforts has an important bearing on our competitive position over the long haul.

The economy objective is becoming increasingly important in military aviation as the size, complexity, and cost of each vehicle is forced upward by performance demands. All the wishful thinking to the contrary, the answer does not lie in a deliberate return to the simple things, because the simple things will not be capable of doing the job. Rather it must lie in the direction of carefully guiding our requirements and our development work to achieve the most adequate air security at minimum cost.

How Long a Step?

The manner in which the various objectives are compromised and the degree of progress achieved in each depend upon the combat mission involved, the state of the art at the time of design, and the expression of requirements from the military services. The latter may, theoretically, represent a forward step of any length but, practically, must represent a step that will give the necessary balance between prompt delivery and

(*Continued on page 125*)



Evolution of Naval Aircraft, 1911–1954

By Rear Adm. Lawrence B. Richardson, USN (Ret.)

Graduate, U.S. Naval Acad., 1917. M.S. in Naval Const., M.I.T., 1921. Naval aviator since 1925. Deputy Chf., BuAer, Nov., 1943. Retired 1946. Held executive positions with Curtiss-Wright and Fairchild before joining General Dynamics, 1951, as Dir. and a Sr. V.P. and V.Chm. of the Bd., Canadair.

FROM THE DAYS OF its first airplanes in 1911, the United States Navy has presented aeronautical engineers with complex and challenging problems in airplane development, design, and construction. Airplanes for operation over the sea, from its surface, and from ships, have always contended with conditions different in many important respects from those encountered by land-based aircraft. That these handicaps have been overcome, and modern high-performance naval aircraft developed, reflects immense credit on the Navy, the aeronautical research organizations of the nation, and the aircraft industry.

The designers of naval airplanes—seaplanes, flying boats, amphibians, and especially carrier-based types—were always faced with demands for high performance and light weight on the one hand, while on the other hand utilitarian qualities were emphasized by the people who must "keep them flying" in the Service. The most successful airplanes have naturally resulted from the most intelligent compromises between performance (in which we include flying qualities), weight, and serviceability. Those aircraft designing and manufacturing companies that have survived and prospered while serving the Navy through the years deserved their rewards for ingenuity, patience, thoroughness, and—above all—engineering skill.

Of course, the Navy itself has contributed tremendously to the progressive development of its aircraft.

No single group of personnel—operating officers, aeronautical engineering officers, or civilian engineers—could or has done it alone, but all of them have participated in an excellent organization with superb spirit. They were determined that the U.S. Navy should have the best naval aircraft in the world—and they saw to it that this came to pass.

One price of progress, which the Navy has been willing to pay in order to speed the evolution of naval aircraft, has been trouble with new types. Almost without exception during the two decades of naval aircraft evolution between the world wars, each new airplane type had to be "grounded" several times in its early months of service for correction of deficiencies of one kind or another. Of course, this was objectionable to the operating units, who complained that new equipment was being placed in service before being adequately tested, but it was the consistent policy of the Bureau of Aeronautics to encourage new developments and to introduce them into regular Fleet service at the earliest possible time, even at the cost of "headaches" and troubles galore. In those days, the only sure way to discover, quickly and thoroughly, what was wrong with new equipment was to get it into regular routine

operations. Flight testing did not reveal all the troubles that the run-of-the-mine operating units soon discovered.

By concentration of the many diversified talents of its aeronautic organization on development, design, evalution, and rigorous operations, the Navy has progressed in a consistent and orderly way, and at a generally excellent rate through the years, from the elemental Wright and Curtiss aeroplanes and hydroplanes of 1911 to the truly remarkable naval aircraft of 1954.

Our tracing of this evolution divides itself naturally into two methods or sequences: first, a chronological method, and second, a method that follows the development of the several categories or basic classes of naval aircraft—e.g., large seaplanes, carrier types in general, fighting airplanes, attack airplanes. Perhaps a combination of the two methods will be the most logical.

The Early Years

The Navy gave no official recognition to aviation until 1910 and had no aircraft or aviators until 1911, when Glenn Curtiss and his pilot, Eugene Ely, were able to arouse the Navy's interest by their courageous and enterprising feats of landing on and flying from a platform on the U.S.S. "Pennsylvania" and landing a "hydro-aeroplane" alongside the ship and hoisting it aboard.

During the 6 years preceding the first World War, the Navy's aviation activity was almost entirely experimental, both on the operating side and the technical side. In general, the effort in this period was concentrated on aircraft capable of operating from the water and on the devices necessary to launch them from ships. Naval constructors and engineers contributed importantly to the improvement of aircraft in general, and particularly by their developments of hulls and floats for seaplanes. The original catapults were also devised by naval constructors in this period for launching seaplanes. Between 1914 and 1917 the Navy applied itself to the problems of taking airplanes to sea on existing types of war vessels and did nothing toward the aircraft carrier as a type.

Flying Boats

The hostilities of World War I, so far as our Navy was concerned, involved not fleet combats but antisubmarine warfare. Accordingly, the previous plans for operating aircraft on ships of the Fleet were dropped, and patrol and bombing airplanes became the important types. The Navy undertook, in conjunction with the British, the rapid development of seaworthy long-range flying boats for antisubmarine operations. This period saw the emergence of the twin-Liberty-engined H-16 and F5L, which were American adaptations of a British original, which in turn could trace its ancestry back to the early work of Glenn Curtiss.

The culmination of this program was the NC series of large four-engined flying boats, designed for long overwater flights and for crossing the ocean if necessary. All but one of them came to grief in the transatlantic flight of May, 1919, but much valuable knowledge and experience had been gained from their design, construction, and operation.

It is interesting to note that no other four-engined flying boats were procured or built by the U.S. Navy for the next 16 years. However, many officers urged the Navy to concentrate on flying boats, and development of these was continued through the early 1920's at the Naval Aircraft Factory. The PN series, based originally on the F5L configuration, introduced such innovations as aluminum-alloy hulls and wing frames and constantly improving power plants. In the middle 1920's, the Navy was ready to purchase the new-type flying boats in "quantity" (25 airplanes from one manufacturer), and the PN was chosen as the prototype of the Douglas PD and, later, the Martin PM series. Both companies had had experience with large airplanes and were well able to cope with their problems.

Progress in flying-boat design was accelerated in the early 1930's, and an additional competitor, the relatively young Consolidated Aircraft Corporation entered this field with a monoplane. The Navy's development policy (and shortage of funds) during these years resulted in many orders of flying boats, but only a few of each design. This had obvious disadvantages from the operating point of view, but it facilitated the prompt introduction of new ideas and improvements.

In 1933, Consolidated Aircraft Corporation submitted the design of the PBY-1 flying boat, an all-metal cantilever monoplane of clean aerodynamic design and an efficient hull. This series, which had reached the PBY-5 version by 1939, was the basic patrol plane of the Navy during World War II. Large numbers were built in the U.S. and Canada, in both the boat and the amphibian configurations.

By 1938 the Navy saw the need for flying boats of higher speed, longer range, and better armament. The Martin PBM-1 was initiated at this time. Its original design held promise of a relatively light flying boat of outstanding performance and load-carrying capability. For a number of causes, many of them due to the early experiences in World War II, the airplane was greatly changed before production deliveries were made. The PBM (Mariner) series of flying boats, on which development continued throughout the World War II program, is an example of the adverse effects that major changes in military requirements—all adding structural weight and military load—can have on an otherwise good airplane. Nevertheless, the Mariners gave a good account of themselves in the war, and many features of their design have been carried into the later Martin flying boats.

Four-engined flying-boat development was resumed in 1935 with the Consolidated PB2Y (Coronado), having four R-1830 engines. This became an extremely large and heavy airplane, but its efficient and sturdy hull, habitability, and sea-keeping qualities made it a valuable adjunct to Pacific operations. Much was

learned from the PB2Y-3 model, and this knowledge was applied to the post war program, as well as to the development of the Martin Mars four-engined flying boat. This very ambitious craft, with a full load weight of about 160,000 lbs., was the largest water-based airplane yet projected in this country. It was originally intended to be a patrol bomber (PB2M), but because of many difficult problems in adapting suitable armament and armor to the airplane and because its speed was too low by the standards of 1944, the Navy decided to redesignate the Mars as a cargo transport (JRM). As such it has operated most efficiently and carries a percentage of useful load to gross weight as great as, if not greater than, any other large airplane.

Experience with flying boats in antisubmarine warfare during World War II taught many lessons, and after the war the Navy and Martin collaborated in the development of the twin-engined P5M Marlin series, specially designed and equipped with every modern device needed for its mission. A comprehensive hull development program resulted in the important new features incorporated in this airplane to improve seaworthiness, take-off and landing characteristics, and handling qualities on the water. The speed and range of the P5M show the benefits of long experience in flying-boat development, combined with the power of the most advanced engines in the R-3350 series.

The design trends in flying boats can readily be traced from this brief outline of history. As in all classes of airplanes everywhere, the steady increase in horsepower of engines made possible better performance and load-carrying qualities. Decrease in specific fuel consumption made greater range possible. Continuous research was conducted on hull forms, step arrangements, and all the qualities tending toward better performance on the water. This knowledge, combined with more attention to the reduction of parasite drag and the ability to accomplish it, resulted in improvements in flying-boat performance at least as great, relatively, as in contemporary large landplanes (admittedly there was a tremendous field for improvement in the seaplanes if one looks back to the characteristics of an F5L, for example).

As World War II ended, the gas turbine became the object of much attention, both in the pure jet and the propeller turbine versions. The latter appealed particularly to the Navy at that time. The Navy had conducted a design competition early in 1946 for a new patrol bomber flying boat of long range and heavy military load. The original specifications did not permit use of gas turbines in the power plant of this airplane, and the designs submitted by the competitors, based on the largest available piston engines, did not offer a sufficient advance over the Martin Mars to justify the effort and money for development of any of them. Accordingly, the Navy issued new specifications, permitting propeller turbines to be selected as power plants, and the new competition was won by the Consolidated Vultee Aircraft Corporation's design, which became the P5Y and R3Y series of water-based airplanes. In addition to adopting the "turboprop" power plants, these seaplanes incorporated the most advanced hydrodynamic and aerodynamic knowledge available. Their performance on the water showed major advances in take-off and landing characteristics, and their performance in the air was approximately equal to that of World War II fighting planes. The aerodynamic and hydrodynamic characteristics of this seaplane were more compatible than in any previous water-based airplane.

The innovations in completely new water-based airplanes (no longer to be known as "flying boats") will be discussed at a later point in this paper, together with other postwar naval aircraft that represent major advances in the science and art of naval aeronautics.

Landplane Patrol Bombers

The Navy found in World War II that long-range landplanes were required to supplement its flying boats in both the Atlantic and Pacific areas. Since there had previously been no such types in naval aviation, the Navy obtained Air Force bombers (heavy and medium) and modified them for naval uses. Such converted bombers could not be so satisfactory for the purpose as airplanes designed as naval patrol planes from the beginning, and the development of the Lockheed P2V (Neptune) series was undertaken by the Navy in early 1943. This has proved to be an efficient long-range airplane—it still holds the world's record for distance without refueling—but its weight has increased because of additional equipment, heavier engines, and the other customary elements of airplane "growth." It seems clear that a new design will be necessary in the near future if the landplane patrol type is to be continued in the Navy. Since U.S. naval aviation must be ready to operate long-range patrol missions in parts of the world where temperatures and sea conditions make seaplane operations impracticable, the land-based patrol and search airplane appears to be a permanent part of the Navy's equipment. The new airplane would naturally be larger than the Neptune and could be expected to be a conventional air frame, probably with four piston engines of the compound type for serviceability and economy at low altitudes.

Ship-Based Seaplanes

One class of naval aircraft on which much development effort was expended during the 1920's and 1930's was the observation–scouting seaplane for operation from battleships and cruisers. Operated by launching from catapults and landing alongside the ships, these small rugged float-type seaplanes were an important part of the equipment of every capital ship until the end of World War II. Progress in these types was never startling because of the difficult problems involved, although the able effort exerted produced many valuable airplanes over the years, notably the original Vought Corsair (O2U) class. Several attempts

at amphibians were made in order to have more versatile airplanes, but none of these was really successful for this sort of shipboard operation. In 1937, the Vought OS2U series was introduced, with modern high lift and lateral control devices. This airplane was about the best that could be developed for this kind of service within the weight and size limitations of shipboard use. It continued in service until the observation-scouting airplanes were removed from the cruisers and battleships, but its performance was such that it was not actually a combatant airplane. With the development of practical helicopters, the ship-based observation seaplane has disappeared from the Naval scene.

Carrier-Based Airplanes

The most interesting categories of naval aircraft, from the standpoints of their challenge to designers and the variety of problems they present, have been the carrier-based types. It is in these that the greatest progress has been made, especially during and subsequent to World War II.

As we look back to the original carrier airplanes, operated from the U.S.S. "Langley" from 1922–1927, we realize what makeshifts they were. However, the basic composition of carrier air groups and the missions or purposes of the aircraft comprising the groups were rather well indicated in those years. The early carrier fighting planes were adaptations of similar Army pursuit types, but soon the long procession of specially designed carrier fighters commenced, with Curtiss, Boeing, and then Grumman being, in turn, the leading suppliers. Tactical scouting was a natural mission for carrier airplanes, and the scout class appeared in the air groups of the "Langley." Torpedo-dropping landplanes also had their beginnings in this period, with the introduction of the Douglas DT series (the first single-strut large airplane). These were the forerunners of the carrier-based torpedo and horizontal bombing class, which developed slowly until Douglas brought out the monoplane TBD in the mid-thirties, based on his transport airplane, the DC-1. This was one of the milestones in progress of carrier airplane development.

In 1927, the addition of the great carriers "Lexington" and "Saratoga" gave the Navy immensely more freedom to develop larger, faster, longer range carrier airplanes. The fighter and torpedo plane-heavy bomber classes continued to progress, and a new class, the scout dive bomber, appeared in the early 1930's. Dive bombing had originated and been developed in U.S. naval aviation (it is not known exactly where or in what unit, but by 1925 this form of attack was being practiced by both Navy and Marine Corps squadrons). This naturally added to the problems of designers of carrier aircraft of both the fighter and scout classes. Methods of stress analysis were revised, and new methods were adopted to cope with the high-speed dives and sharp recoveries or "pull-outs." Structural design of naval fighter and dive-bomber aircraft introduced innovations that later became universal.

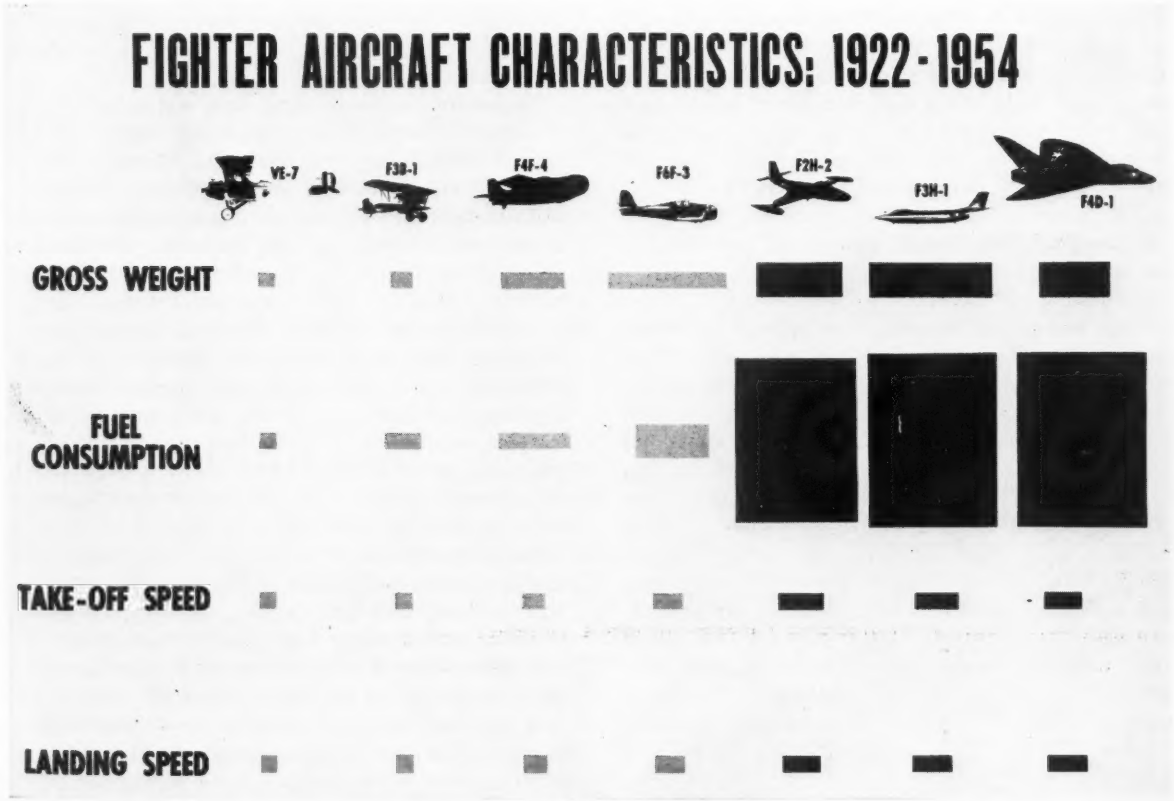


Fig. 1.

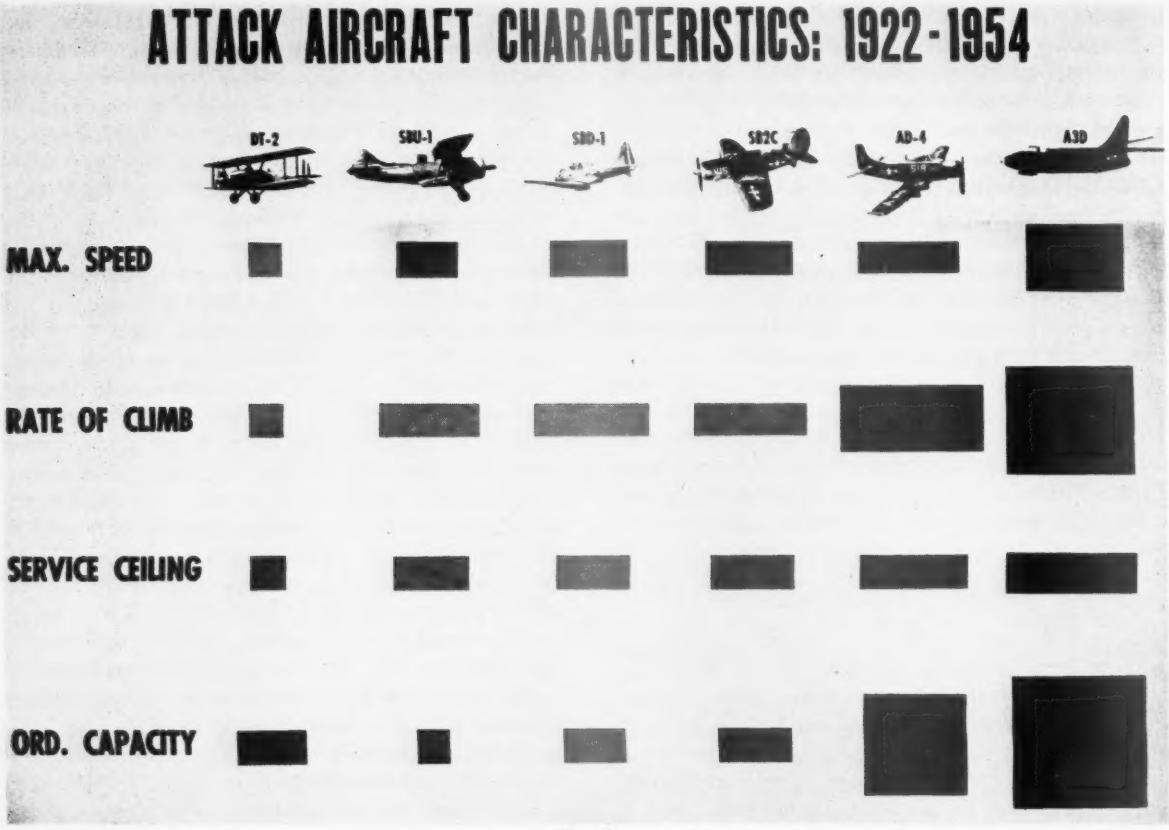


FIG. 2.

Sizes and speeds of the carrier airplanes of the 1920's and early 1930's, and their range and load-carrying capacities, were limited by their ability to take off from the carriers' decks under their own power and to have their landing runs arrested by the existing arresting devices. These two conditions resulted in limiting the take-off speeds of carrier airplanes to low figures (it is easy to remember specifications requiring that minimum level flight speed with power at full load must not exceed 65 knots).

During the 10 years prior to World War II, Naval aviation was gaining experience and storing up knowledge in the use of carrier aircraft in the Fleet. There were many theories and doctrines, and consequently many different classes and types of airplanes were tried, with some strange combinations of missions and purposes. It was a first-class, full-scale laboratory. An example of a theory that came and went during the 1930's was that some two-place fighters were needed in carrier groups. Several attempts were made to develop suitable airplanes on the principle that the pilot on certain missions needed a rear gunner. However, in each case the opponents of this principle won their point (abetted by relatively inferior airplane performance), and the two-place fighters became scout-bombers. The trend away from rear-seat gunners was illustrated by the Curtiss single-place bomber-fighters of 1933–1935 and, later, by the omission of the second man from attack airplanes. Pilots agreed that the additional speed and reduced weight, achievable by abandoning flexible guns and gunners, were better protection than the guns.

The introduction of flush-deck catapults in the "Enterprise" and "Yorktown" (1935–1936) enabled heavier loaded airplanes to be launched. Carrier catapults have been continuously improved in capacity and speed through the years. The same has been true of arresting gear capacity, and the combined result has been a steady increase in the allowable launching and landing speeds of carrier airplanes. Consequently, it was feasible continuously to increase the high speed, range, armament load, and total weight of carrier-based airplanes, thereby keeping pace with the steady increase in power of engines and taking full advantage of it. Graphic indications of these changes in fighter and attack airplanes are given by the charts in Figs. 1 and 2, furnished through the courtesy of the Assistant Secretary of the Navy for Air.

The Navy entered World War II with three basic classes of carrier airplanes: (1) fighters, all fitted for dive bombing with light bombs; (2) scout-bombers, fitted for dive bombing with medium bombs; and (3) torpedo-bombers, fitted for horizontal bombing with heavy bombs or for launching torpedoes. Nearly all these airplanes had been developed from what might be called peacetime specifications, and in most cases they were not fitted with armor or self-sealing fuel cells; most of their guns were 0.30 cal., and power turrets

were conspicuous by their absence. New types of airplanes with latest armament and protection were entering production, but they were from 8 months to 2 years away from readiness for service in the Fleet. Accordingly, it was necessary to make urgent military changes in the existing types and to rush similar changes into the new production lines where not already specified. These things, of course, added to the weights and reduced the performance or range, but the lesson had been learned. These features—heavy machine guns, power turrets, armor protection for the crew, and rubber protection of fuel tanks—became permanent standard requirements of combatant naval aircraft.

While these features were incorporated into all airplanes accepted thereafter, the airplanes themselves were of prewar designs. However, their characteristics were based on intelligent application of years of rigorous experience. Carrier aviation at sea is a hard taskmaster even under peacetime conditions, and as a matter of sheer necessity the aviation organization of our Navy had developed a series of serviceable airplanes, well suited to their respective missions.

Of course, all types of naval aircraft (in common with Air Corps types) were continuously developed throughout the war production program, and the airplanes delivered in 1944 and 1945 were much superior to their early prototypes in military effectiveness, reliability, and overall perfection as machines and as weapons. The intense engineering and inspection effort on the part of thousands of people intelligently applying their concentrated experience brought the airplanes to a state of perfection never before realized.

All-Weather Fighters

The naval night-fighter airplane originated as a type during the war and developed rapidly. The first examples, of course, were modifications of existing single-place day fighters, which were made night fighters by loading them with additional electronic and other equipment. Evolution was naturally toward use of these airplanes in unfavorable visibility and ceiling conditions during daylight, as well as darkness. "All-weather" operation from carriers presents additional problems of a more difficult nature than does similar operation ashore, and it was necessary to develop Navy-type airplanes for this.

Difference of service opinion exists in the Navy (as also in the Air Force) on the question of one- or two-man crews for all-weather fighters. One two-place type was initiated at about the war's end, and several single-place adaptations of wartime and postwar fighters have been tested in service. It seems generally agreed that eventually, when automatic electronic aids shall have been perfected, the single-place all-weather fighter will be practical for carrier use and the two-place airplane will disappear from this type of service.

So much for the status of the evolution of naval airplanes at the end of World War II. Let us now examine the developments during the past 8 years—a period of rapid progress such as had not previously occurred. It has been called the time of the technical revolution in aeronautics.

Postwar Carrier Airplanes

After the war ended, the Navy was able to continue development of several important airplane types that had been undertaken during the last year of the war. Progress on these was naturally slowed down, both because of reduced budgets and because of the desire to take advantage of the lessons of the war, combined with the latest technical advances. In the general category of piston-engined airplanes, the various functions of the scout-dive bomber and torpedo plane-horizontal bomber were combined in one class, designated "attack" airplanes. Douglas Aircraft devoted much attention to the AD (Skyraider) series, which has developed into an exceedingly versatile and serviceable type. The loads of bombs, guns, rockets, and fuel, with which the AD airplanes are launched from carrier catapults, are little short of miraculous. This series of carrier airplanes is an excellent example of intensive development through close cooperation of the Navy and one of the most experienced specialist companies in the carrier airplane field.

A new type of attack airplane—the multiengined heavy bomber type—was given a service test in carrier units after the war. In order to carry loads too great for any single-engined airplane of acceptable performance, it was necessary to accept the disadvantages of size and weight and the operating difficulties of multiengined airplanes on carriers. Thanks to increasing capacity of catapults and arresting gears and to good design and careful testing, there are now no serious problems in operating North American AJ (Savage, see Fig. 3) long-range heavy attack airplanes from the large carriers. This experience will stand the Navy in good stead when it becomes necessary to operate twin-turbojet attack airplanes (the Douglas A3D, see Fig. 4) in the relatively near future.

The AJ uses two piston engines and one turbojet, a combination that originated with the Navy-Ryan FR

Fig. 3. North American AJ-1 Savage.

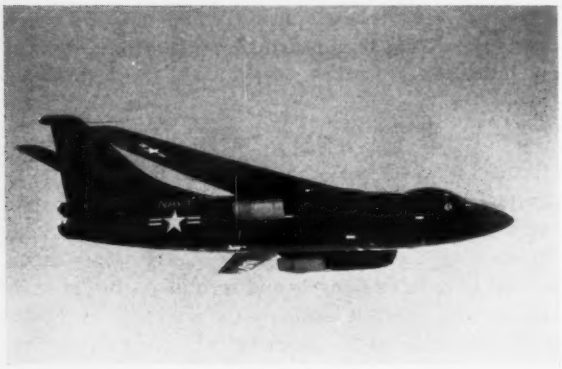


FIG. 4. Douglas A3D.

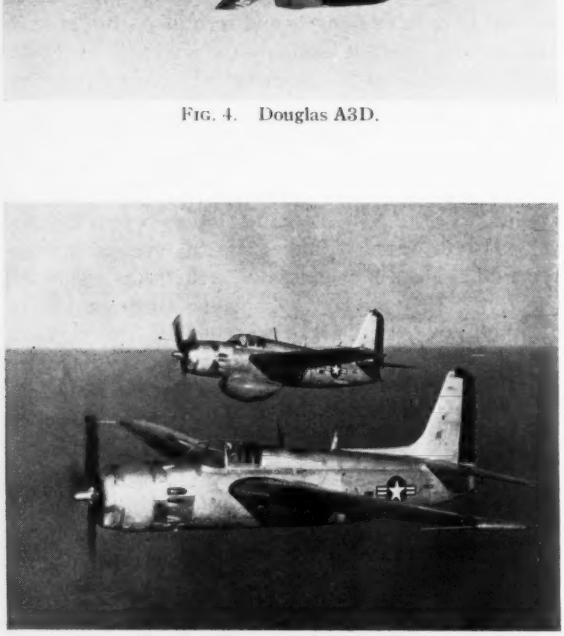


FIG. 5. Grumman AF Guardian.

FIG. 6. Grumman S2F-1.

fighter in 1943 and that has been applied in principle to several other aircraft. It gives the airplane the economy of piston engines for cruising, plus the reserve of jet power when needed over the target area. This combination, however, is considered only a stop-gap until serviceable turboprop engines are available for this class of naval aircraft.

"ASW" Aircraft

Antisubmarine warfare has been given high priority by the Navy, and naval aviation plays a vital part in the search for submarines and attack on them. The flying boat and long-range land-based patrol airplanes have their natural places in this kind of warfare, but carrier-based airplanes have proved to be immensely valuable as well. Carriers can hunt and kill submarines in any climate and on any sea when equipped with special antisubmarine attack planes. The Grumman AF "Guardian" (see Fig. 5) is the current service type and is the largest single-engined carrier airplane in the Navy today. These airplanes operate in pairs—a "hunter" and a "killer"—i.e., a search plane with extensive detection equipment and an attack plane with offensive weapons. In more recent years, it was decided to develop an antisubmarine airplane that could perform both the search and attack missions, in order to reduce the number of units on the carrier. The design competition for this combination airplane was won by the twin-engined Grumman S2F (see Fig. 6), which will soon be service tested. It is another example of the difficult problems faced by designers of naval aircraft, and its successful development will reflect great credit on the engineering organization responsible for it.

Postwar Seaplanes

Water-based airplane development after World War II proceeded slowly. Mention has already been made of the Consolidated Vultee P5Y and R3Y series, based on a new design shortly after the war. This four-turboprop flying boat has been retarded by a long series of difficulties with the power plants, but the prototype has been operated sufficiently to show the excellent results of the hydrodynamic innovations and refinements incorporated in its hull—extended afterbody, high length-to-beam ratio, refined bottom and step lines, and excellent bow configuration.

The use of propeller turbines in large water-based airplanes has the same advantages as in landplanes—good take-off characteristics and fuel economy better than turbojets. Propellers, of course, are vulnerable to water damage and, consequently, must be located on a high wing, but the superior spray control and good planing qualities of modern hulls minimize the vulnerability.

On the other hand, turbojet power plants for water-based airplanes offer speed advantages not obtainable with propeller turbines. Jets, in combination with planing-tail hulls, allow the use of slim aerodynamically refined forms. A high-speed turbojet-powered flying boat, the Martin XP6M, is under development for the Navy, and much will be learned from it. It is believed that the trend illustrated by this design will guide the development of ultra-high-speed water-based airplanes of large size, which may at some future date dominate the real long-range transport of pas-

sengers and possibly carry the largest military loads to the greatest distances.

A radical departure from past seaplane development was taken in the Consolidated Vultee Sea Dart (Navy XF2Y, see Fig. 7), turbojet powered and equipped with retractable water skis for take-off and landing. This seaplane fighter airplane has tremendous possibilities, provided, of course, that in due time it will demonstrate good rough-water operation and ease of handling and recovery. It is not hard to visualize a number of practical uses for a seaplane that can take off not only from water but from catapults of aircraft carriers, which can land not only on water but also on various other surfaces, and which can base aboard a carrier, a tender, or ashore.

As in any radical new development, there are problems to be solved before the Sea Dart is a fully serviceable naval aircraft, but the design trend that it exemplifies is one of greatest importance. It brings water-based aircraft performance into favorable competition with that of landplane types, which is an epoch-making event in the history of naval aviation.

FIG. 7. Consolidated Vultee Sea Dart.

JET-POWERED CARRIED AIRPLANES

Turning back once more to the closing months of World War II, let us review the introduction of jet-powered airplanes into our carrier squadrons and the development of jet types during the intervening 8 years.

In 1943 the Navy authorized McDonnell Aircraft Corporation to design a twin-jet-powered fighting airplane for carrier operation, believing thereby to explore the feasibility of jets on carriers. Progress of this development was necessarily slow for various reasons (higher priority for programs "to win this war" was the principal one), but the airplane (FH-1 "Phantom") was very successful when completed.

As the war with Germany ended, information on the startling advances in jet propulsion which the Germans had made brought home to our Navy the urgency of jet airplanes for carrier use. The 400-knot fighters of World War II became obsolescent overnight, and even Congress began to look askance at Navy fighters with propellers attached. It was evident that for carrier aviation to continue its great importance, future carrier aircraft had to measure up to the standards of the past.

It was obvious from the beginning that range (or endurance) would be the most important factor determining the serviceability of jet airplanes on carriers. Of great interest also, and a cause for concern, was the problem of launching them from carriers and landing them on board. Many questions were raised, such as would the higher approach and wire-engaging speeds make arresting the jet airplanes on deck impracticable, and would it be feasible to get them off?

Since economy of fuel was so important and affected airplane size and weight so much, thought was given to multijet aircraft—even six- to twelve-engined designs were discussed. Fortunately (or unfortunately), there were no gas turbines of such small size, and the Navy decided on the twin-jet McDonnell Phantom for the initial service testing. It began its carrier landings in July, 1946, being the first jet airplane to land aboard.

Near the end of the war and soon thereafter, additional experimental contracts for jet fighters were awarded to North American Aviation for the FJ-1 Fury and to Chance Vought Aircraft for the F6U Pirate. All of these early types started with the basic concept that good carrier operation was the first consideration. Stalling speeds were kept as low as possible (90 knots was held by many to be the absolute upper limit), and the best take-off characteristics were a mandatory requirement. Of course, these limitations had major effects on maximum speeds.

However, as the Navy and the aircraft industry gained more experience with jet fighters, progress became bolder and more rapid. Grumman entered the jet fighter program with the rugged Panther series, which saw combat service in the Korean war and is now being superseded by the swept-wing Cougar, actually a transition type. The Panther was the Navy's first tactically operational jet fighter, although the first squadron operations on the U.S.S. "Boxer" had been with the original North American Fury. McDonnell's second carrier fighter, the F2H "Banshee," showed a

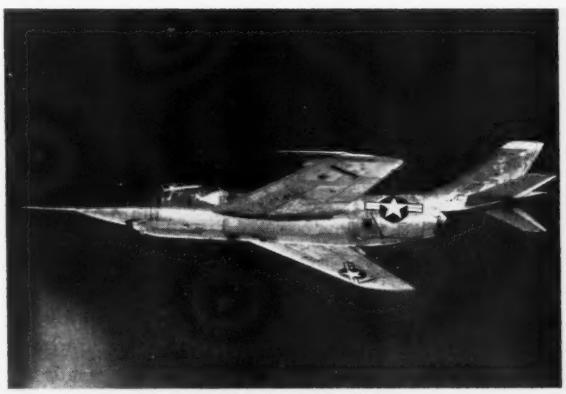


FIG. 8. McDonnell XF3H-1.

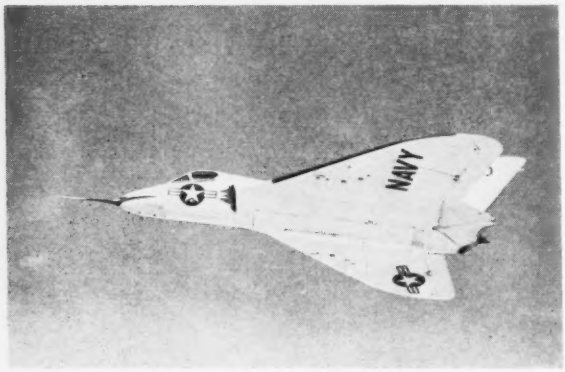


FIG. 9. Douglas F4D Skyray.

real advance over the original Phantom. Following its predecessor by only 2 years, the Banshee was over 100 m.p.h. faster and had a 5,000-ft. increase in operating altitude, in addition to changing armament from 0.50-cal. to 20-mm. guns. McDonnell has now developed the F3H Demon (see Fig. 8), which can be expected to show a comparable further advance.

Douglas entered the carrier fighter field after the war and has already become a potent factor with the F4D Skyray (see Fig. 9). This airplane, on October 3, 1953, captured the world speed record at 753.4 m.p.h., the first service-type carrier fighter to hold this record.

Chance Vought Aircraft, developer of the F4U Corsair fighter (the only piston-engine fighter to be kept in service after World War II) won a Navy design competition in early 1946 with the F7U Cutlass, at the time a very unusual configuration. The experience gained with the Cutlass fighter and its all-weather version will stand the Vought organization in good stead in designing a newer carrier fighter, recently undertaken.

North American Aviation's latest Fury (see Fig. 10) is now being introduced. It is a carrier version of the famous F-86E "Sabrejet" of the U.S. Air Force. This is the first time such a direct adaptation of a land-based fighter has been made to carrier service. Obviously, there are increases in military load, gross weight, and wing area, but the airplane is basically the same. This is a step well worth watching.

The last 5 years have seen such increases in performance, especially in various research airplanes and other experimental projects, that there has been an ever increasing struggle for higher speeds, greater rates of climb, and higher ceilings. This trend has, of course, involved larger and larger power plants, requiring more and more fuel, in turn requiring more structural weight and larger airplanes, with continuously increasing gross weights. At the same time, optimism with regard to electronic devices led to adoption of a great assortment of such things. Increased demands on the pilot, incident to higher speeds and altitudes, led to added demands for automatic devices to relieve the pilot work load. Higher air loads increased the demand for more power-actuated controls. The necessity for reliability of airplanes with so many complex systems and devices (hydraulic, electric, and electronic) led to much parallel duplication of components. All of these trends combined to project carrier fighter airplane gross weights into the 25,000—30,000-lb. category, and the weight figures were spiralling steadily upward.

Most of our carriers were built for World War II airplanes, and it became clear that the Navy was coming to a parting of the ways with regard to the airplanes and the carriers from which they operate. It was mandatory that the carriers be improved by developing catapults and arresting gears of greater capacity. Demands for higher landing speeds (arresting gear engaging speeds) created the requirement for longer arresting run-out. This, combined with the difficult barrier and barricade problem to stimulate the adoption of the "canted deck" arrangement (see Fig 11), on the U.S.S. "Antietam," the first carrier so equipped in our Navy. This permits a minimum number of arresting gear units, with longer run-outs at higher speeds. This will eventually permit reducing structural weight of carrier airplanes for two reasons: (1) longer run-outs result in lower arresting stresses on the airplane, and (2) utilizing the "power-on" landing technique results in lower sinking speeds and, consequently, reduced shock on landing and reduced strength requirements in the airplanes.

In catapult development, which is equally vital to carrier aviation, the trend has been not only in the direction of increased energy-giving capacity, but also especially in the direction of increased power strokes, reduced mass of moving parts, and other improvements of like nature. The newly developed British steam catapult, adopted by the U.S. Navy, has energy greater by a factor of ten than that of the catapults on the "Essex" class carriers.

However, as the rapid and alarming increase in weight of carrier aircraft became evident to the Navy, steps were taken not only to improve the carriers and their equipment but also to obtain lighter and simpler airplanes for the various purposes. There began a campaign (almost a crusade) to simplify and lighten naval aircraft. It is difficult to say to whom the credit

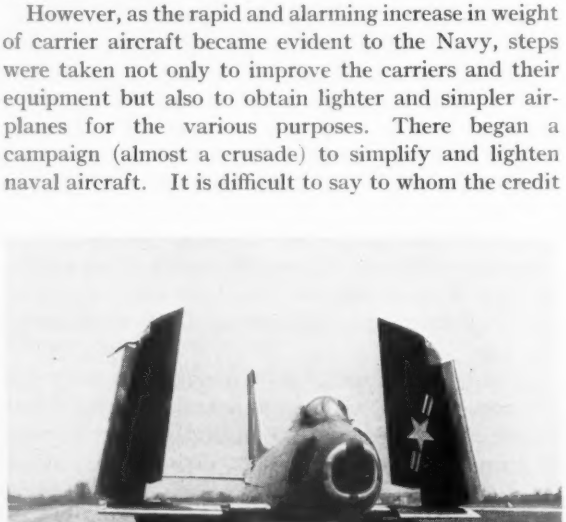


FIG. 10. North American FJ-2 Fury.

should be given for this reversal of the weight-increase trend, but Ivan H. Driggs, of the Bureau of Aeronautics, and Edward H. Heinemann, of Douglas Aircraft Company, Inc., were among its original proponents. In any case, the most recent programs of experimental naval aircraft are largely built around these considerations.

There are cynics who point out that many attempts have been made through the years to design lightweight simple naval aircraft. These attempts, say the cynics, were chiefly on paper, and none of the airplanes ever became a service type. The reason for this was that essential things such as adequate armament, crew and fuel tank protection, power, or fuel supply had to be compromised. Rather than lighter airplanes, they have become heavier, larger, and more complex with every new model. It will be necessary to counteract this kind of thinking if the campaign for weight reduction is to be supported and given a real chance of success.

In this connection, much credit is due the Hon. John F. Floberg, former Assistant Secretary of the Navy for Air, for his attitude. The following is quoted from an article written by Mr. Floberg in February, 1953, which expresses the thinking of those responsible for recent trends in the lighter direction.

"Recent trends have seen aircraft weight, size, and complexity spiral to alarming heights, causing some sacrifices in performance and necessitating certain compromises which we have accepted so that performance criteria of speed, altitude, and other essential factors can be met. A consciousness of the dangers involved should such trends be allowed to continue has been stimulated in aviation circles both by industry and the military. As a result, aircraft design requirements are being re-evaluated to determine military worth and to investigate the necessity of specification design features presently prescribed. Because of this action, the alarming growth-and-complexity trend can be eliminated, I believe, and perhaps the trend may even be reversed downward, so that the superior performance so essential to operational requirements can be more readily achieved. This can only be done through ingenuity and through the application of a philosophy which considers design features of minimum weight, minimum size, and overall simplicity to be of paramount importance—importance second to none and equivalent only to essential aircraft combat performance."

The constant urge for longer range ("greater combat radius") for carrier airplanes, without excessive increase in size and weight, forces the Navy to seek all practicable means of reducing fuel consumption. The early jet fighters gave carrier captains many an anxious hour, wondering whether the airplanes had enough fuel to get back to the ship and go through the landing procedure. Any means of "stretching the gas" of a carrier turbojet airplane is of vital interest. One method that is applicable to jet-powered carrier fighters is the two-engined principle. As related above, the earliest Navy jet fighters were two-engined, and efforts have been made to continue this policy, although the limited availability of turbojets of suitable size and power has necessitated adoption of single-engined configurations in some cases. The two-engined installation permits full power for take-off and combat, yet it permits greatly increasing endurance and range by stopping one engine while cruising, patrolling, and "loitering."

FIG. 11. U.S.S. "Antietam."

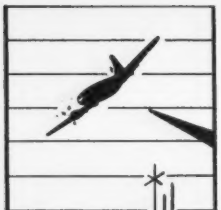
Nearly all turbojets now in production are of high thrust, all on the increase, and there is none in the medium range (about 5,000 lbs.), which appears to be the optimum for Navy twin-jet fighters. It is believed that the Navy will initiate development of one or two new turbojets in this class.

Since powerful catapults are, or will be, available on carriers, take-off runs are not a major problem. Modern practice is to make all carrier take-offs by catapult launching. This policy is applied even to piston-engined airplanes, such as attack planes, when heavily loaded.

During the early years of aircraft carrier operation, it was accepted doctrine in naval aviation that carrier airplanes were unavoidably inferior in performance to the corresponding classes of land-based airplanes. This was considered to be true because of the structural strength and weight required for carrier operations; the limitations imposed by these operations on take-off and landing speeds; the greater fuel capacity required in carrier airplanes; and the increase in weight, size, and wing area and the consequent decrease in speed with equal power resulting from all these handicaps.

However, evolution of naval aircraft and carrier equipment subsequent to World War II and the projected future developments both of airplanes and carriers indicate definitely that this situation is changing. Unceasing insistence on most careful and skillful aerodynamic and structural design, emphasis on simplicity, and elimination of nonessential weight and military load are reducing the sizes and automatically improving performances within available power and wing-loading limitations. In the future, it will be possible to accept higher wing loadings by virtue of the more powerful and faster catapults and of the canted decks of carriers.

(*Continued on page 126*)



Design Trends—Transport

By A. E. Raymond

With Douglas Aircraft Co., Inc., since 1925. Began as Metal Worker, only position then open. Soon transferred to Engineering Dept., becoming Assistant Chief Engineer in 1927 and Chief Engineer in 1936. Appointed to present position as V.P.—Engineering in 1939. Member of NACA since 1946.

I HAVE BEEN DEPENDENT upon Carlos Wood, who is in charge of preliminary design at the Douglas Santa Monica Division, to assemble the material that comprises the main body of this article. It covers in some detail the history of the past 50 years in transport aviation and makes some broad guesses as to the future. The illustrations are by Florence Wright.

As an introduction, it might be appropriate to mention the developments that seem to me to be among the most influential in bringing air transport to its present efficient state:

(1) Someone had to prove that powered flight was possible. This devolved upon the Wright Brothers.

(2) As long as a forced landing was the inevitable consequence of every engine failure, transport aviation, especially the transport of passengers, was severely handicapped. The advent of the multiengined plane, capable of continuing flight with one or more engines dead, was therefore of primary importance.

(3) Next, I would list stressed-skin construction, which made clean exteriors and roomy interiors possible.

(4) Concentration of effort on the air-cooled radial piston engine, and its constant improvement in power output per pound of weight, in fuel consumption, and in time between overhauls, has had a great influence in making air transport into a business that could be operated at a profit.

(5) This has been greatly assisted by concurrent advances in propeller design, including automatic adjustment of pitch and reversible pitch to assist landing.

(6) Wing flaps have improved landing and take-off, while permitting reductions in wing area to decrease drag in flight.

(7) The tricycle landing gear has assisted the landing operation and ground handling in general.

(8) Pressurization has enlarged the choice of operating altitudes and made it normal to fly above most turbulence and much of the bad weather.

(9) Navigation and communication systems, both air-borne and ground-installed, have been perfected to such a high degree that virtually all-weather operation is practicable and safe.

(10) Highly skilled operational and maintenance techniques have grown up during this period which have contributed substantially to the present record of safe, regular, and dependable service.

All aircraft from the Wright Flyer itself have been used to transport persons and things. The Wright Flyer transported Orville Wright

120 ft. in 12 sec. that morning of December 17, 1903—50 years ago. The fourth and last flight of that first morning transported Wilbur Wright 852 ft. in 59 sec.—the most rapid rate of air-transport growth and speed in history.

In those early days and up to almost the end of World War I, airplanes were all-purpose—the blessings and curses of specialization were not yet with us. The same airplane was often used for sport, as a fighter, as a bomber, as an ambulance plane, or as a transport—such as it was. The first specialization in the field of air transport seems to have occurred in 1917, when a French physician designed an aerial ambulance that was placed in service in September of that year. A few months later the United States also placed in service an ambulance plane that had been converted from a Curtiss "Jenny."

Another pair of Curtiss "Jenny's" started the official carriage of air mail on May 15, 1918, between New York and Washington. The initial operation was not completely successful, for the northbound plane got lost and landed on a Maryland farm. The Army continued the service until August 12, 1918, when the Post Office took over. Several different airplanes were either designed or modified for air-mail service, including the modified twin-engined Martin bomber, but the mainstays of the air-mail fleet were the modified DH-4's.

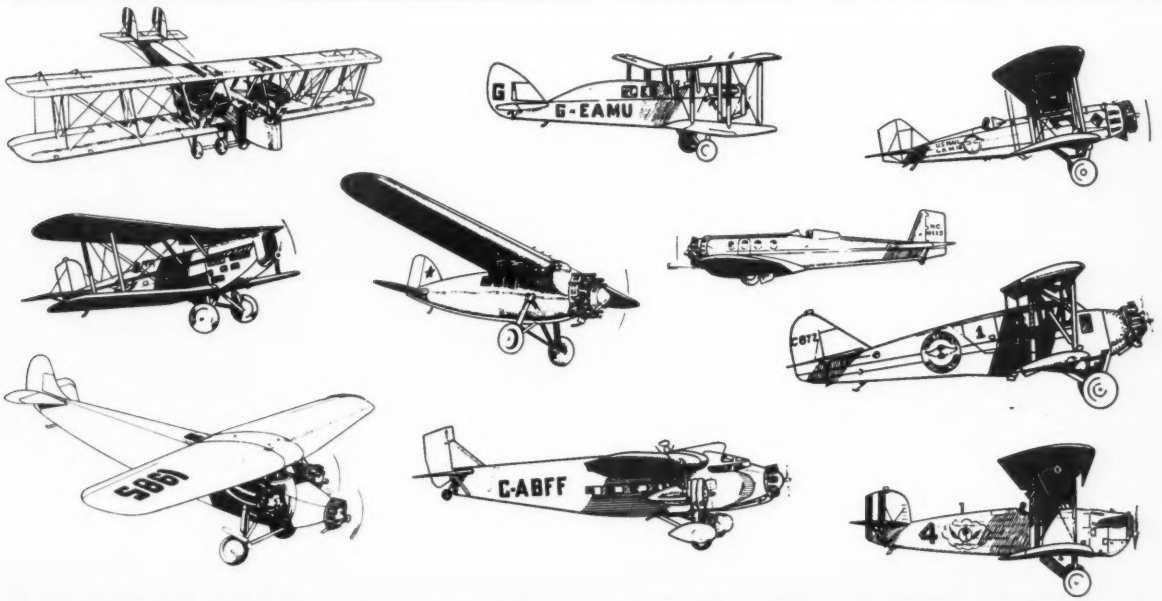
Daylight transcontinental air-mail flights were started in DH-4 mail planes on September 8, 1920, and day-and-night flights were started on February 22, 1921, between New York and San Francisco. Regular night service (with lighted airways) was started on July 1, 1924. The Post Office Department continued to operate the air mail until September 1, 1927, when private contractors took over.

Occasional passengers were carried with the mail beginning in 1926 and 1927. The converted DH-4's were being replaced by more specialized airplanes such as the Boeing 40, the Douglas M series, the Lockheed Vega, and other single-engined types.

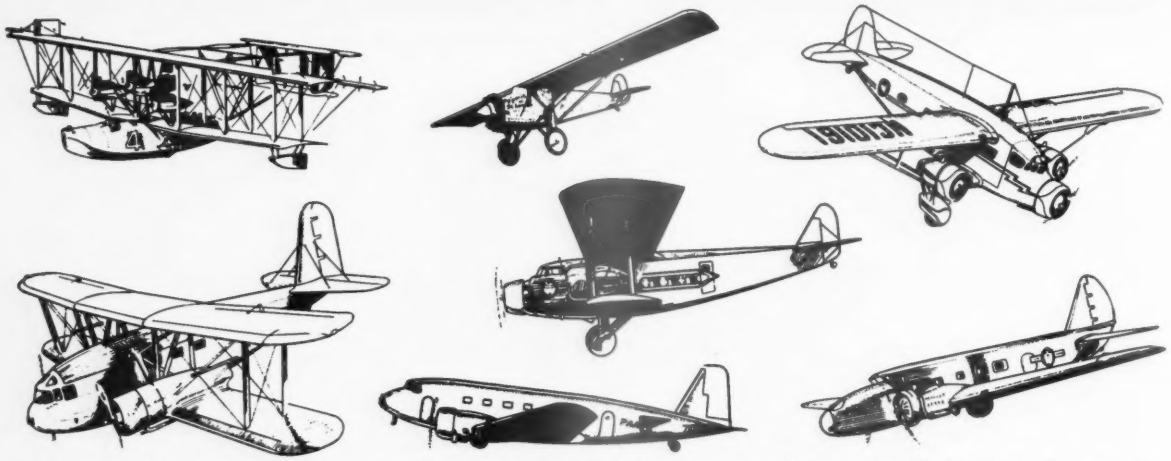
Demand for passenger service continued to grow, and this resulted in the introduction of multiengined airplanes, such as the Fokker Trimotor in 1926 and the Ford Trimotor in 1928. These airplanes had essentially equivalent capacity, twelve passengers for the Fokker F-10, and eleven to thirteen for the Ford 5-AT-B, carried at cruising speeds of 118 and 115 m.p.h., respectively. The simplicity of air transports of this period is best shown by the airplane costs: $35,125 for the Fokker; $37,600 for the Ford.

Even by this early date airplane design had specialized to the point where the transport airplane had emerged as a distinct genus—a new type of airplane had been born.

Up to this time flying was of short range, except for a few Government-sponsored flights such as those of the Douglas World Cruisers in 1924, the NC-class flying boats across the Atlantic, and the like. These were all in military airplanes and under conditions anything but conducive to large-scale air travel. Then, on May 20–21, 1927, a lone young man, in a single-engined airplane developed from a line of strictly commercial airplanes, made a long-distance flight that caught the imagination of the world and sparked the world's interest in aviation which continues to rise to this day. Lindbergh's flight from New York to Paris was the



Top row: Martin bomber; DH-4; Boeing 40. *Center row:* Douglas M; Lockheed Vega; Boeing monomail; Stinson biplane. *Bottom row:* Fokker Trimotor; Ford Trimotor; Douglas World Cruiser.



Top row: NC-4; Spirit of St. Louis; Stinson Trimotor. *Center:* Boeing 80-A. *Bottom row:* Curtiss Condor; Douglas DC-1; Boeing 247.

catalyst that started aviation, particularly air transport, along the path and growth that still is continuing.

More long-distance flights followed Lindbergh's, and more and more of them were in commercial-type transport airplanes.

By the early 1930's, the Fokker and Ford trimotors were dominating the commercial airways of the United States, and transport of mail, cargo, and passengers began to have regularity, safety, and utility. The Stinson Trimotors, the Curtiss Condor bimotor, and the Boeing 80-A trimotor biplane were also in wide use.

Search for speed, economy, and overall efficiency caused designers to restudy the fundamentals of airplane design, and about 1932 the first results of their work began to appear. The Boeing 247 all-metal twin-engined monoplane was put in service by United Air Lines and scored a clean beat of the field.

TWA couldn't take this beating lying down and went to the industry to get a plane that would be superior to the Boeing 247. Douglas won the contract. The first flight of the Douglas DC-1 was in 1933, and TWA started operations with the DC-2 in 1934.

With the Boeing 247 and the Douglas DC-2 the needs of the air-transport passenger underwent a significant change. Instead of having to be capable of taking a physical beating and having sufficient money for the fare, it was only necessary to have the money, since the new airplanes provided comfort almost to the point of relative luxury, as well as high speeds, low sound levels, and ability of the air line to operate economically.

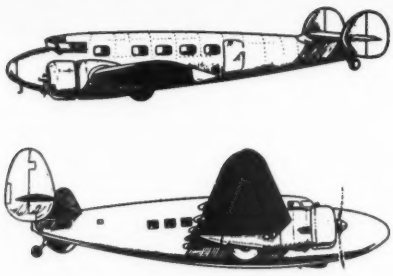
But this part of the story was not quite finished. American Airlines was still flying Curtiss Condors, much slower than the new airplanes, and had started to provide sleeper service. But competitively they were behind United and TWA, and something had to be done about it. The Condor was incapable of matching the Boeing and Douglas transport speeds. The Douglas DC-2 had a larger air frame than the Boeing 247 and thus was more adaptable to American's plan, which was to get a sleeper plane of the same speed as that of the new transports. Working with Douglas, the DST was put in service in 1936. The DST used the DC-2 wings, landing gear, fuselage, nose, and tail. It had a wider fuselage and longer tips on the wings to increase the span from 85 to 95 ft. It had larger tail surfaces to go with the wing and more powerful engines.

DC-2.

Then someone noted that it was possible to put three rows of seats in the DST, instead of the two being used in the DST as a sleeper, the DC-2 as a day plane, and the Boeing as a day plane. This immediately increased capacity pay load by 50 per cent, which could be carried by the larger engines available, and the DC-3 was a fact.

With the DC-3 the air lines finally had a fast modern airplane that could carry enough passengers comfortably at a low fare to permit air transport to really develop a market and grow. The DC-3 shortly dominated the world's air lines. Over 400 were in air-line service before World War II, over 11,000 were built as C-47's during World War II, and at the end of this first half-century after the Wright brothers' first flight, it is still the most widely used air transport in the world. Actually, there are probably more DC-3/C-47's in service today than any other airplane, regardless of type. It is used for everything—from exploration to executive transport to scheduled or unscheduled air transport of goods, freight, people.

Lockheed had also begun to interest itself in the transport field and produced the ten-passenger Model 10 Electra in 1933, essentially with the same performance as the Boeing 247 but somewhat more roomy and comfortable. This design was followed in 1937 by the 14-passenger Model 14 Lodestar, which was powered by the same engines and cruised considerably faster than the DC-3.



(*Top*) Lockheed Model 10 Electra.
(*Bottom*) Model 14 Lodestar.

From these developments began to appear information needed for the design of successful air transports—airplanes that could be successful business tools that would permit profitable operations by the air lines. The basic conflicts between speed, power, pay load, maintenance requirements, ground facilities, airport requirements, and design for safety were resolved in various ways in all of these transports, the several compromises were tried in the open market, and the returns were available for analysis and future development of advanced type transports.

Experience showed that the prime requisite for successful air transports was suitably low operating cost. Speed at the expense of suitable operating cost was not acceptable. Low airplane weight and high aerodynamic efficiency were essential to a suitable operating cost. Ground facility and airport requirements out of the normal trend were not acceptable, even if direct operating cost had to be sacrificed, for total operating costs got out of hand. Suitable comfort levels (not necessarily luxurious levels, but easily bearable ones) were mandatory, or the transports would not attract sufficient passengers, regardless of direct operating costs. Last, but by no means least, the transport must be capable of flight and operational regularity and safety, in weather and emergencies, or the service presented was not dependable and safe enough for a large number of passengers to be attracted.

The requirements for design safety were developed from the experiences gained with these airplanes, and by joint development between the Civil Aeronautics Administration, Civil Aeronautics Board, and the air-transport manufacturers and operators, a set of transport design requirements was evolved, known as the "T-category" or C.A.R. Part 04 requirements. Similarly, operating requirements were developed. Subsequent developments, and those still to come, are all within the framework of these requirements, as originally developed and still under continuous modification.

With improved aircraft, improved operations, and a really salable type of air transportation available, the air-transportation business grew by leaps and bounds. Being perennial optimists (you had to be to get into this business in the first place), the engineers, designers, and operations people agreed that bigger, better, and faster transports should be designed and built—and right away.

Accordingly, American, Eastern, TWA, United and Pan American jointly went to Douglas for the design of a new, large, four-engined airplane to have the best and most modern of everything—brand new engines, especially developed for the DC-4E; brand new electrical system, alternating current instead of direct current; brand new auxiliary power plants, to make the DC-4E self-sufficient on the ground; brand new tricycle landing gear, for extra safety in landing and take-off; brand new hydraulically boosted controls, for greater ease of flying; brand new triple tail, low enough so existing hangers could be used; brand new cabin supercharging, for greater comfort; brand new standards of luxury and space for passengers, for greater comfort.

From this revolutionary airplane concept, great lessons were learned. Complexity upon complexity and revolutionary design finally combined to give the project growing pains that could not be satisfactorily solved in the time and at the period required. Aerodynamic, mechanical weight, and efficiency problems prevented full realization of design goals for the DC-4E. The onset of World War II in Europe took some of the bloom off the air-transport market, and the air lines became uneasy about the large size of the DC-4E and the passenger loads required for profitable operation. Only one DC-4E was ever built. Trying to make too big a jump, revolutionary instead of evolutionary development, resulted in an inferior airplane for the contemporary transport market.

While Douglas was working with the DC-4E, Boeing was taking another approach. The B-17 four-engined bomber was in production for the U.S. Army Air Force and was in a good state of model development. Its four engines were turbosupercharged, which made possible flight at high altitudes, higher than transport passengers could stand. Accordingly, Boeing decided to take the B-17 air frame, essentially complete except for the fuselage, equip it with a large diameter pressurized fuselage, and produce it as the Boeing Model 307 Stratoliner pressurized four-engined transport. This

airplane, the first really operational airplane of the four-engined high-altitude era just opening, was close enough to the requirements of TWA and Pan American so these airlines each purchased a few of them and placed them in service beginning in 1940.

After binding up their wounds and indulging in a course of critical analysis of the deficiencies of the DC-4E, the Douglas designers made a reanalysis of the four-engined transport design problem, turned to, and produced a much simpler, somewhat smaller, and vastly more efficient airplane in the DC-4. It was obvious

that this new airplane was much better suited to the market, and it was in series production for American, United, and Eastern air lines at the end of 1941 when World War II suddenly struck the United States and, again, all bets were off.

The immediate requirement when World War II started was for transport of all types. Thousands of miles separated the United States from the active war theaters, and although most goods and personnel must obviously be carried by surface transport, there was a "must go" demand for rapid transport of critical personnel and goods. The demand was immediate, and accordingly transports-in-being were the first requirement. New production was the next requirement, and new specialized models were desired as they could be made available. Attempts were made to violate this order of priority during World War II but without success.

At the initial shock of World War II, the armed services were in dire need of tactical aircraft. Maximum emphasis was put on these at first and for a short time practically to the exclusion of air transports, except for the DC-3/C-47, which for some time, at least in certain quarters, was considered to be the only type of transport required. It was even being suggested that what "small" requirement there was for long-range air transport could be furnished by converted bombers such as the Boeing B-17 and the Consolidated B-24.

Realization of the limited space capacity of these tactical airplanes, combined with the extreme need for bombing aircraft and the development of the necessity for large amounts of long-distance air lift, forced acceptance of long-range air transports as a requirement within a few months.

Transport airplane designs were under continuous modification during World War II to increase pay load-range capabilities and to permit carrying progressively heavier and larger items of military equipment. Heavy-duty floors, large loading doors, cargo tiedown provisions, convertible-type cabins became the rule so that the same airplane could be rapidly changed from transporting personnel to carrying general cargo, replacement engines, ground-force equipment, and the wounded. The last modification became extremely important, since it was early found that air transport of wounded was a major factor in minimizing deaths from battle injuries or sickness, because the casualties could be placed in suitable hospital facilities very rapidly.

Production of DC-3/C-47's was accelerated immediately after the start of the war, with 810 airplanes being accepted in calendar 1942; 2,413, in 1943; 4,900, in 1944; and 1,488, through August 1945, for a total of 9,211 through these 4 war years. In addition, the armed services took over about one-half of the air-line DC-3's at an early date, and 131 C-117A's were procured in 1945.

Curtiss-Wright, in 1940, had under development a large twin-engined transport known as the CW-20, which was designed to be competitive with the Boeing B-307 and the Douglas DC-4 four-engined transports. When World War II came the CW-20 was well along in development and was in a state that made it available for production. Whereas the C-47 was used primarily for cargo in the early war period, it was moved more into paratroop and personnel transport as the war progressed and we went on the offensive. The requirements for cargo lift still existed, and because of its larger size, the armed services felt that the CW-20, renamed the C-46, should be used for cargo operation.

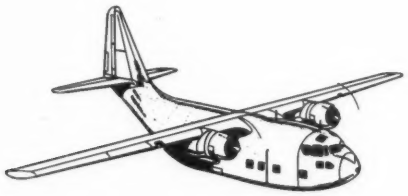
The C-46 was put into service as rapidly as possible in spite of the many difficulties to be expected in any new design that has not had the advantage of an antecedent family. Acceptances of C-46 airplanes were 26 from June through December, 1942; 335, in 1943; 1,321, in 1944; and 1,459, through September, 1945, for a total of 3,141 airplanes.

Several abortive attempts were made to design new twin-engined transports, none of them successful in obtaining production during the war but finally leading to a specialized military transport that has become the forerunner of today's low-floor type of military tactical transports.

Because of worries about a shortage of aluminum due to terrific expansion of military aircraft production and a feeling in some quarters that transport airplanes could do with less quality than tactical airplanes, several attempts were made to design transports of other materials.

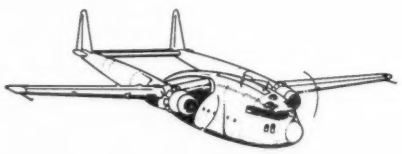
One of these airplanes was the Budd C-93, designed of stainless steel. But stainless steel was finally found to be in shorter supply than aluminum. This fact, plus the successful production of large numbers of other transports such as the C-46 and C-47 and the presence

of the usual new airplane problems, finally caused the cancellation of the 600 airplanes on order. The C-93 is notable in that it was a low-floor, high-wing design with an upswept tail and a rear loading door—somewhat like today's Chase C-123.



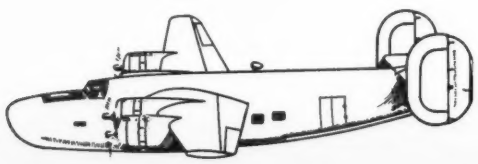
The Waco C-62 and Curtiss-Wright C-76 designs were designed to be of wood and plastic construction, during a time of abundance of these materials. By the time the airplanes were to be constructed, these materials were in short supply, and aluminum was plentiful. New airplane problems, plus a lot of subcontracting problems, finally resulted in the cancellation of the C-62 and the production of only 25 C-76's.

The last of this group of tactical twin-engined transports was the Fairchild C-82. Initially a wooden design in 1940, it was finally changed to all-metal construction and was built that way. It was originally slated for early production, but with construction and the usual new airplane problems the first C-82 was not delivered until June, 1945, and a total of six was delivered through 1945. The C-82 and its replacement, the C-119 series, have stayed in production up to the present time and have become pretty much the armed forces standard tactical air transport.



The only long-range airplanes available in quantity at the beginning of World War II were the Boeing B-17 and Consolidated B-24 four-engined bombers. In addition to these airplanes, a few Boeing B-307 transports were in use by the air lines, and 24 Douglas DC-4's were under construction for the air lines. Boeing was out of production on the B-307 and had their hands full accelerating B-17 production, so further B-307 production was unavailable.

Consolidated had proposed a transport version of the B-24 just prior to our entry into the war but had been turned down because of high demand for bombers.



After Pearl Harbor, however, transport became so critical that B-24's were stripped and used as transports, and in June, 1942, procurement of transport versions got under way as the Consolidated C-87. One hundred ninety-one C-87's were procured from September, 1942, to August, 1944. Also, the requirements for gasoline lift across the "Hump" into China caused the conversion of 204 B-24's to gasoline transports by the end of 1944. The bomber conversion of the B-24, as in most other cases, did not produce an efficient transport airplane, and therefore more emphasis had to be placed on transport procurement.

As mentioned above, Douglas was in process of building 24 four-engined DC-4's for the air lines. At the first shock of Pearl Harbor, the military reaction was that construction should be stopped and all efforts concentrated on tactical types. This reaction quickly evaporated as the shortage of transport became apparent, and all 24 DC-4's, renamed the C-54, were delivered to the Air Force between March and October, 1942. Beginning in December, 1942, the C-54A and subsequent variations were delivered, and by the end of 1945, being built at two plants, a total of 1,163 C-54 transports had been accepted. The original DC-4 had been designed for domestic air-line ranges and a gross weight of 50,000 lbs. Long-range operation required the use of fuselage fuel tanks. As rapidly as possible, additional fuel capacity was designed into the wings, and the later versions of the C-54 had a gross weight of 73,000 lbs. These changes, plus the installation of cargo floors and fittings, large loading doors, and other military facilities, resulted in the C-54 developing into the most efficient long-range transport airplane of its day.

With the ever increasing demand for long-haul air lift, it appeared that larger transports should be developed. Accordingly, in January, 1942, Douglas proposed the developments of a large long-range four-engined transport of about double the capacity of the C-54. This proposal, after several modifications, was accepted as the C-74, and procurement of 50 of the airplanes was approved in February, 1942. The

program was adversely affected by higher priority production of tactical aircraft at Douglas and by design changes. The order was finally reduced to 14 airplanes, of which only one was accepted by December, 1945. Development of the C-74 by the incorporation of a new and larger fuselage with integral nose loading ramps has in later years resulted in the C-124, still in series production as the standard heavy cargo transport of the U.S. Air Force.

In 1939, after it appeared that the Douglas DC-4E would not go into production, TWA approached Lockheed regarding the design of a long-range high-speed pressurized-cabin airplane, and in the greatest secrecy a contract was signed for nine Model 049 "Constellation" airplanes. Pan American added an

order for 40 airplanes, 18 of which were higher gross weight, longer range Model 149 airplanes. At the same time, TWA increased its order to a total of 40 airplanes.

With the growth of the Air Corps production program, it became apparent as early as the summer of 1940 that the Constellation program had to be curtailed in favor of the P-38 fighter program. In May, 1941, Lockheed agreed to limit the Constellation program to the design and construction of three prototype airplanes, but in December, 1941, the critical demand for long-range transports changed this program to permit completion of all 80 Constellations on order, and the Air Corps contracted with TWA and Pan American for the airplanes. In January, 1942, the Air Corps contracted with Lockheed for the construction of 180 Model 349 airplanes capable of carrying task force equipment for long range. It also advised Lockheed to abandon Model 149 and restrict production of Model 049 to 50 airplanes. As can be seen, things were getting somewhat confused in the whole program, and accordingly the Air Corps decided that it wanted to deal directly with Lockheed.

Finally, an agreement was worked out to establish deliveries as follows: nine Model 049 to TWA by July, 1943; 41 Model 049 to Army Air Forces by January, 1944 (20 as C-69 personnel transports, 30 as C-69A transports for light cargo); and 210 Model 349 (C-69B) to Army Air Forces by October, 1944, as full cargo transports.

It appeared that the Constellation program was finally stabilized. But urgent requirements for Lockheed P-38 fighters took priority over the transport, and the growing number of Douglas C-54's going into service took the heat off of the Constellation program and it was seriously delayed.

To wind up the story (which is detailed as a prime example of difficulties of developing a new transport airplane during wartime), in November, 1944, Lockheed obtained approval to modify the C-69 to 100,000 lbs. take-off weight and 87,000 lbs. landing weight, from the original 68,000 lbs. take-off weight for the Model 049 and the Model 149's 82,000 lbs. In February, 1945, the existing military contracts were modified to leave 73 airplanes in the program, 70 at a gross weight of 86,250 lbs. and three at a gross weight of 100,000 lbs. Finally, in August, 1945, the orders were reduced to 20 light and three heavy model airplanes. Fifteen Constellations were delivered by October, 1945. But with all of the vicissitudes, the Constellation, the first of the postwar 300-m.p.h. 20,000-ft. altitude pressurized cabin, long-range air transports, was off to a running start.

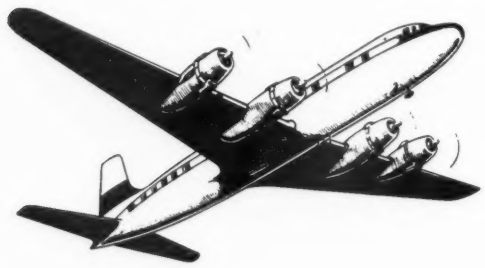
With design developments, and increases in engine power, in design gross weight, and in passenger capacity and comfort, the Constellation is one of today's greatest transports and is in quantity series production. It meets the basic requirements that have allowed today's air-transport industry to come of age, to become economically self sustaining, and to link the great cities and continents of the world in today's world air-line system. The Constellation is also being produced as a cargo airplane and as a special-purpose airplane for the armed forces. Four Constellations are being built up as flying test beds for turboprop engines.

The great demand for long-range transport also resulted in modification of the Boeing B-29 to a transport. An enlarged fuselage was necessary for the Boeing C-97, and therefore a large upper section was built on to the bottom of the B-29 fuselage. High priority of the B-29 program delayed the production of the three XC-97's in the transport program. Accordingly, the Army Air Forces had accepted only two C-97's by the end of 1945. But Boeing went ahead with the commercial version of the C-97 and sold 55

airplanes to the air lines as the Model 377 Stratocruiser, equipped with new and larger engines, with a gross weight of 142,500 lbs. The Stratocruiser is in long-range service and is one of the great postwar transport airplanes. Versions of the Boeing Stratocruiser, as various C-97 models, are still in production for the U.S. Air Force for transport and refueler use.

By 1944 it was obvious to everyone in contact with the air-transport industry that postwar transport business would be large if suitable aircraft could be made available. The fact that it was essential to do a certain amount of planning for postwar markets if the manufacturers were to remain solvent was finally recognized, and in June, 1944, the Air Force decided to legitimize a certain level of development work on postwar transport aircraft. The importance of such aircraft to national security was by this time fully recognized. Approval was given in December, 1944, for the procurement of 13 Douglas C-74's (originally proposed to the air lines as the long-range DC-7 but

subsequently withdrawn from the commercial market), ten Boeing C-97's (Model 377 Stratocruiser), three Lockheed C-69's (Constellation), and three modified C-54E's to be known as Douglas XC-112A, XC-114, and XC-116 (the latter two were to have Allison and turboprop engines, respectively, and were later canceled; the XC-112A was the progenitor of the Douglas DC-6 series transports). In the latter part of 1945



and the first part of 1946, the contracts to Lockheed and Douglas for the Constellation and the DC-6, respectively, were canceled and these airplanes were finally on their own commercially.

The Constellation and DC-6 series airplanes have been the "Big Two" long-range commercial transports of the post World War II era. Both series have sold over 400 airplanes, an unheard of quantity of seat-mile capacity by comparison to prewar air travel. They provide comfortable economical travel over a long range at cruising speeds of over 300 m.p.h. in pressurized cabins at 20,000-ft. altitude.

The Constellation first went into U.S. domestic service for TWA in 1946 and then moved into the overocean travel market. The Constellation has moved through several modifications, from the original Model 049, through the Models 649 and 749 (each of higher operating weight and power), to the present Model 1049 series, with an 18-ft. longer fuselage, and in the "E" version with the Wright Compound R-3350 engine, to cruise at 335 m.p.h. at 23,000-ft. altitude. Speed, range, altitude, and capacity have steadily increased, and direct operating cost per ton-mile has steadily decreased.

The Douglas DC-6 first went into U.S. domestic service for United and American air lines in 1947. The first overocean use was by United between San Francisco and Honolulu and by Scandinavian Airlines System between New York and Stockholm. Growth in both fields has been steady. The DC-6 was originally developed from the C-54E (DC-4) by the incorporation of strengthened structure, larger engines, a pressure cabin, a revised control system, changed windows and accommodations, and lengthening of the fuselage by 80 in. The DC-6 series has had continuous development since its inception, with successively higher operating weights and powers. In 1949, the DC-6A cargo version was flown, being developed in the belief that air cargo required a large capacity fast airplane of high efficiency. This airplane is now being operated in cargo service by several air lines over the world and is playing an important part in the development of air cargo, which many feel will grow into a tremendous business. The DC-6A is also in series production as a cargo and personnel transport for the U.S. Air Force (C-118A) and the U.S. Navy (R6D-1).

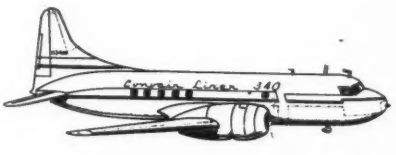
As the DC-6A is 60 in. longer than the DC-6, it has increased passenger capacity and was placed in air line service in 1950 as the DC-6B—Again, more power, more speed, more capacity, and lower ton-mile operating cost.

In 1951, American Airlines approached Douglas regarding an advanced version of the DC-6B, to be called the DC-7, and powered with the same Wright

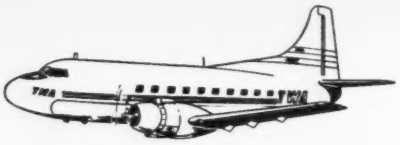
Compound R-3350 planned for the Lockheed 1049E Constellation. This airplane cruises at over 360 m.p.h. at 23,000 ft. and, again, has a lengthened (40 in.) fuselage—thus again, more power, higher speed and altitude, more capacity, and more economy. The DC-7 is in series production for several air lines as 1953 closes, and at this writing American has announced nonstop service between New York and Los Angeles with a schedule of 8 hours or less elapsed time.

As the Constellation/DC-6 battle raged for long-range transport supremacy and these airplanes moved up in capacity and range, specialized transports were necessary to cover the short-haul intermediate-stop market. The DC-3 was still in use for this service but had been passed in speed (it cruises at 170 m.p.h.) and could not practically have its cabin pressurized. Therefore a more modern and more economical short-haul airplane was desired.

Accordingly, in 1947, the Martin Model 202 and Convair Model 240 were placed in air-line service. The airplanes were almost identical in capacity (36 passengers vs. 40), in speed, and in other characteristics. The 202 was not pressurized; the 240 was. A series of unfortunate accidents, plus large and unexpected manufacturing expenses, forced the Martin out of production after only a couple of dozen had been placed in service. The Convair 240 went on to become practically the standard postwar short-haul transport. An improved and enlarged Convair, the Model 340, was



placed in service in 1950 and continues in large-scale series production for many of the world's air lines. Martin also decided to re-enter this field and produced



Model 404 for Eastern Air Lines and TWA. A considerable number of Model 404 was produced for these two air lines, but Convair had the rest of the market well tied up and the Martin has gone out of production.

One last word about the DC-3. In 1949, Douglas developed a major rework of the DC-3, with more power, speed, capacity, and better economy. The Super DC-3 retained its conventional landing gear, and its stretched (39 in.) fuselage was not pressurized. Only three airplanes were placed in air-line service; these have since been retired to corporate use. However, the U.S. Navy has placed in service a large number of these airplanes as the R4D-8. The future of the Super DC-3 commercially is still in doubt, but there is some indication of revised interest on the part of the very short-haul feeder lines that have grown up since World War II.

The future form of aircraft for this very short-haul business is yet to be determined. The imagination of aviation people has been intrigued by the commercial possibilities of the helicopter ever since the Sikorsky VS-300 was developed in 1941. This great advance over the prewar autogiro appeared to have the potential of successful commercial operations.

Development has been continuous and rapid almost from that time, Sikorsky being in small series production of the R-4 as early as 1943, and in quantity production of the R-4 as early as 1943, and in quantity production of Model R-5 in 1944, moving to production of the four-place S-51 in 1945. The first U.S. commercial helicopter license was issued in 1946 by the Civil Aeronautics Administration to Bell on the two-place Model 47.

The U.S. Post Office Department conducted helicopter air-mail tests in 1946 over local routes around Chicago. The Civil Aeronautics Board awarded the first helicopter route certificate to Los Angeles Airways in 1947. By 1948, several manufacturers were active in the helicopter field, such as Sikorsky, Bell, Piasecki, Hiller, McDonnell, Kellett, Kaman, and others. Development has continued, and the helicopter has come into its own for rescue, liaison, and ambulance service during the Korean War. Work is now continuing on helicopters of greater capacity, with plans for twin-engined machines of as much as 40-passenger capacity. These developments are focusing attention on the possible use of the helicopter in very short-haul or feeder air-line service. The main present problems are of how big is the market and how much is the operating cost. Further resolution of these problems will determine the commercial future of the helicopter, but the long-term trend appears to favor the helicopter for such use.

During World War II, Great Britain and the United States agreed on a division of production in the interests of efficiency and effectiveness in the prosecution of the war. Part of this agreement was that the United States would be responsible for the production of transport aircraft. This put Great Britain in a position where her transport development, even of the military type, was essentially brought to a standstill. This situation disturbed many in the British aircraft industry and, accordingly, the Brabazon Committee was formed to develop specifications for British postwar transport aircraft. As is the case with most committee-drawn specifications, the resultant aircraft developments have had many vicissitudes. But the British had a card up their sleeves in the form of their wartime development of the turbine engine, which gave them a great technical lead in the power-plant field immediately after the war. The time has not yet come to determine whether the card is an ace. But United States transport designers have now at least seen some of the cards in the British hand. The postwar British transports are imaginative and without a doubt have opened a new era in aviation —the era of the turbine transport.

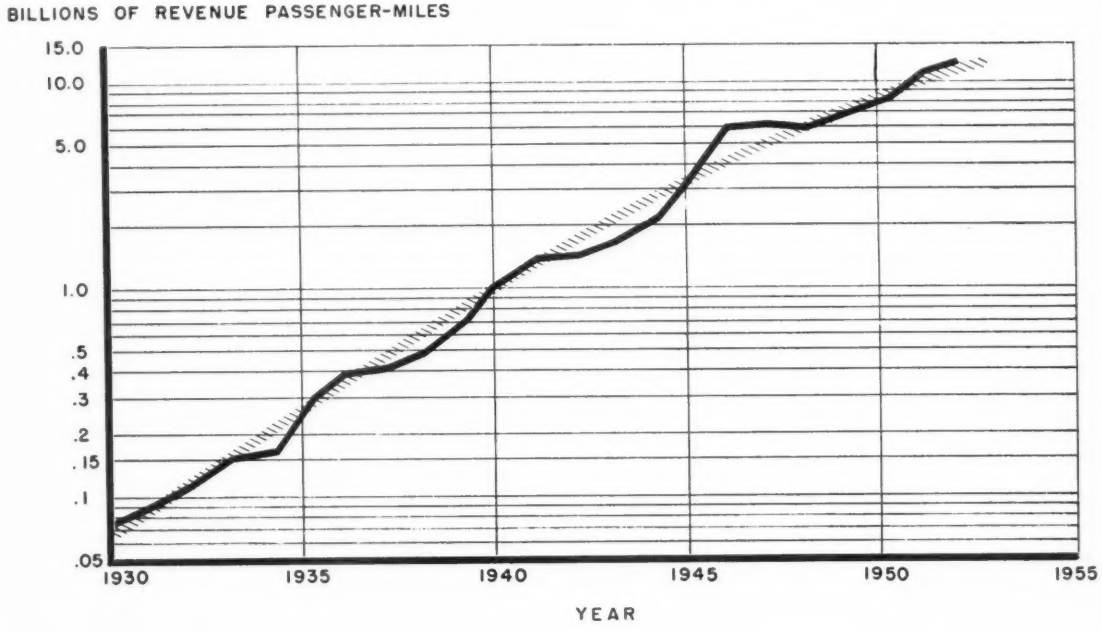
The most widely known postwar British transport is the de Havilland four-engined Comet jet transport. The Comet I was put in service by British Overseas Airways in May, 1952. The Comet II is now in small-scale production for several customers, none of whom is located in the dollar exchange area. The proposed Comet III is under tentative order by Pan American, among other customers. Each of the Comet series in turn has had increased power, speed, range, and capacity and decreased operating cost, following the time-tested development sequence of all successful transports. The Comet has encountered some operational problems. It is an outstanding airplane and is continually improving, model by model. A Comet IV is reported to be under consideration as a greatly changed model, but little is known about it. At present the Comet series (up through the Comet III) has not developed to the point where it meets the economic requirements for successful transports as developed in the United States. Its breakeven point is still about 75 per cent capacity pay load, as compared to the 50 per cent target for U.S. transport designs.

Another less spectacular but solid British postwar transport, used in local service by British European Airways, is the Vickers Viscount four-engined turboprop transport. Advanced models of this airplane are also now under way. A little slower than the Constellation or DC-6, the Viscount is quiet and smooth and has good flying characteristics. It shows promise of becoming a good economical airplane for short to medium length trips.

U. S. DOMESTIC

REVENUE PASSENGER-MILES BY YEARS

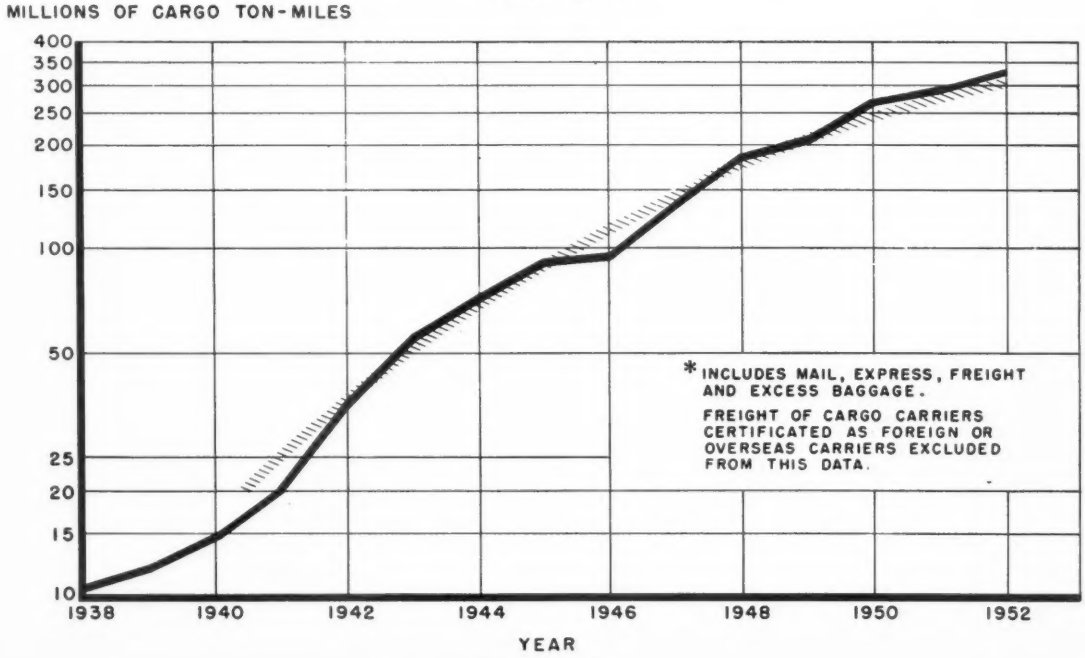
SCHEDULED TRUNK AND LOCAL SERVICE CARRIERS
1930-1952



U. S. DOMESTIC

REVENUE CARGO TON-MILES*

SCHEDULED TRUNK AND CERTIFICATED CARGO CARRIERS
1938-1952



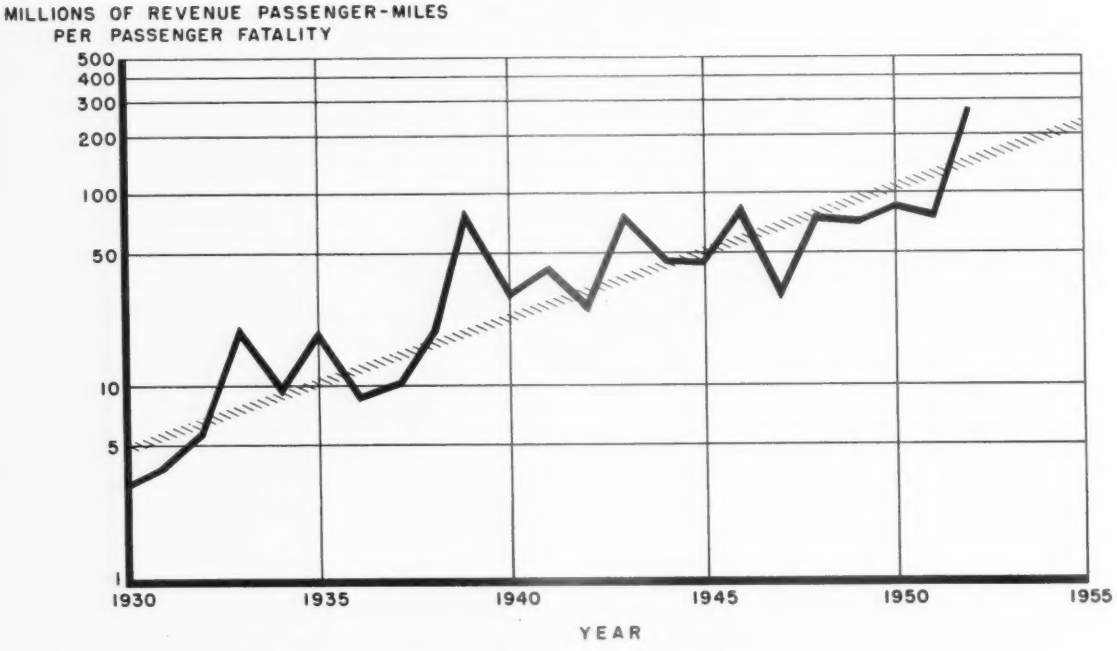
FIGS. 1 and 2.

U. S. DOMESTIC

REVENUE PASSENGER-MILES PER PASSENGER FATALITY

SCHEDULED TRUNK AND LOCAL SERVICE CARRIERS

1930-1952

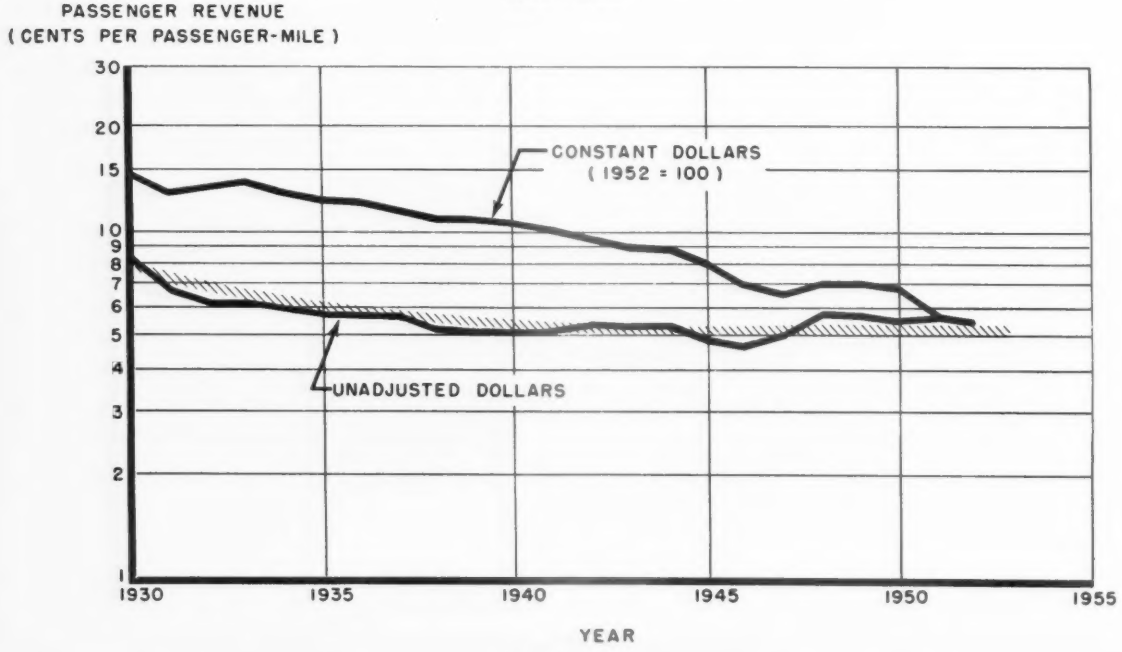


U. S. DOMESTIC

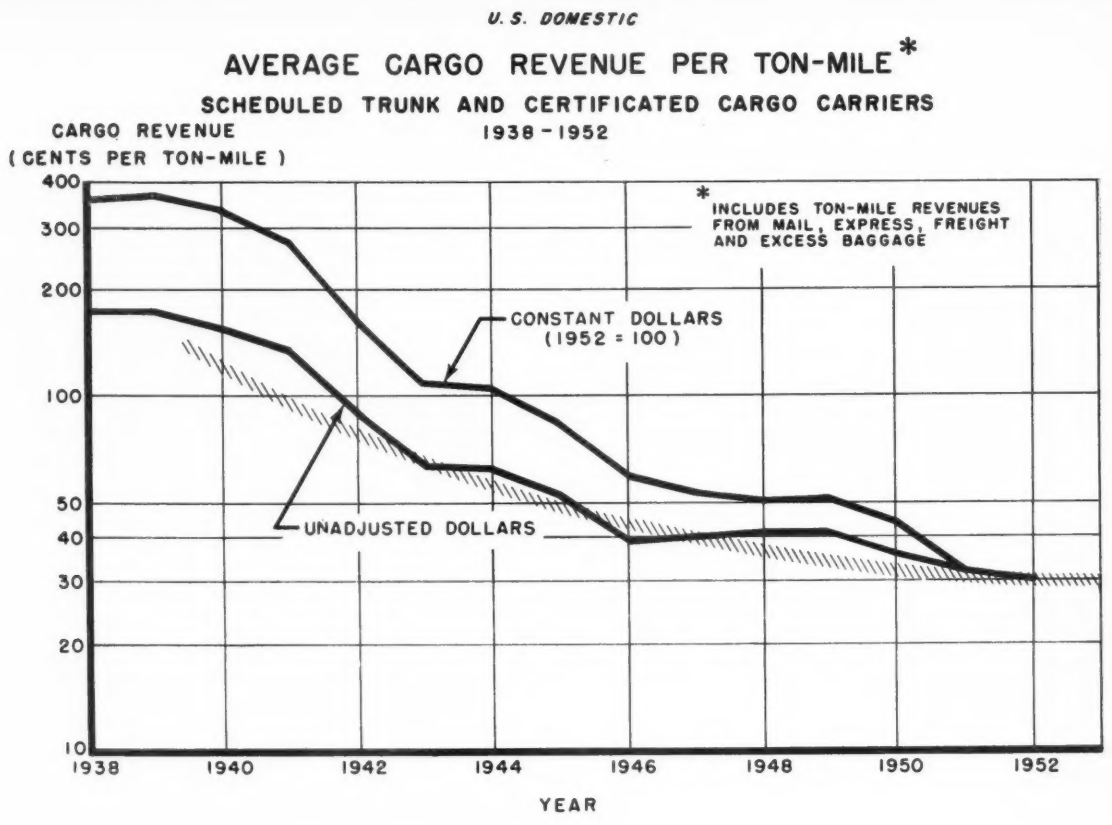
AVERAGE FARE PER PASSENGER-MILE

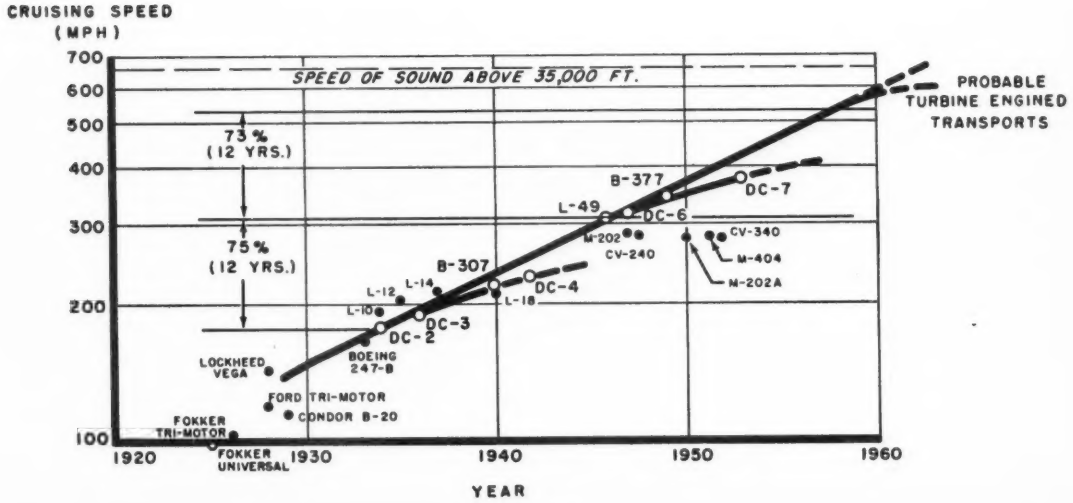
SCHEDULED TRUNK AND LOCAL SERVICE CARRIERS

1930-1952



FIGS. 3 and 4.


U. S. DOMESTIC
AVERAGE CARGO REVENUE PER TON-MILE*
SCHEDULED TRUNK AND CERTIFICATED CARGO CARRIERS
1938 - 1952
CARGO REVENUE
(CENTS PER TON-MILE)
400
300
200
100
50
40
30
20
10
* INCLUDES TON-MILE REVENUES FROM MAIL, EXPRESS, FREIGHT AND EXCESS BAGGAGE
CONSTANT DOLLARS (1952 = 100)
UNADJUSTED DOLLARS
1938
1940
1942
1944
1946
1948
1950
1952
YEAR


TREND IN CRUISING SPEEDS
(LONG HAUL DOMESTIC AIRCRAFT)
1925 - 1960
CRUISING SPEED
(MPH)
700
600
500
400
300
200
100
SPEED OF SOUND ABOVE 35,000 FT.
PROBABLE TURBINE ENGINED TRANSPORTS
73 % (12 YRS.)
75 % (12 YRS.)
B-377
DC-7
L-49
DC-6
M-202
CV-240
CV-340
M-404
M-202A
B-307
DC-4
L-14
L-12
L-10
L-18
DC-3
DC-2
LOCKHEED VEGA
BOEING 247-D
FORD TRI-MOTOR
CONDOR B-20
FOKKER TRI-MOTOR
FOKKER UNIVERSAL
1920
1930
1940
1950
1960
YEAR

Figs. 5 and 6.

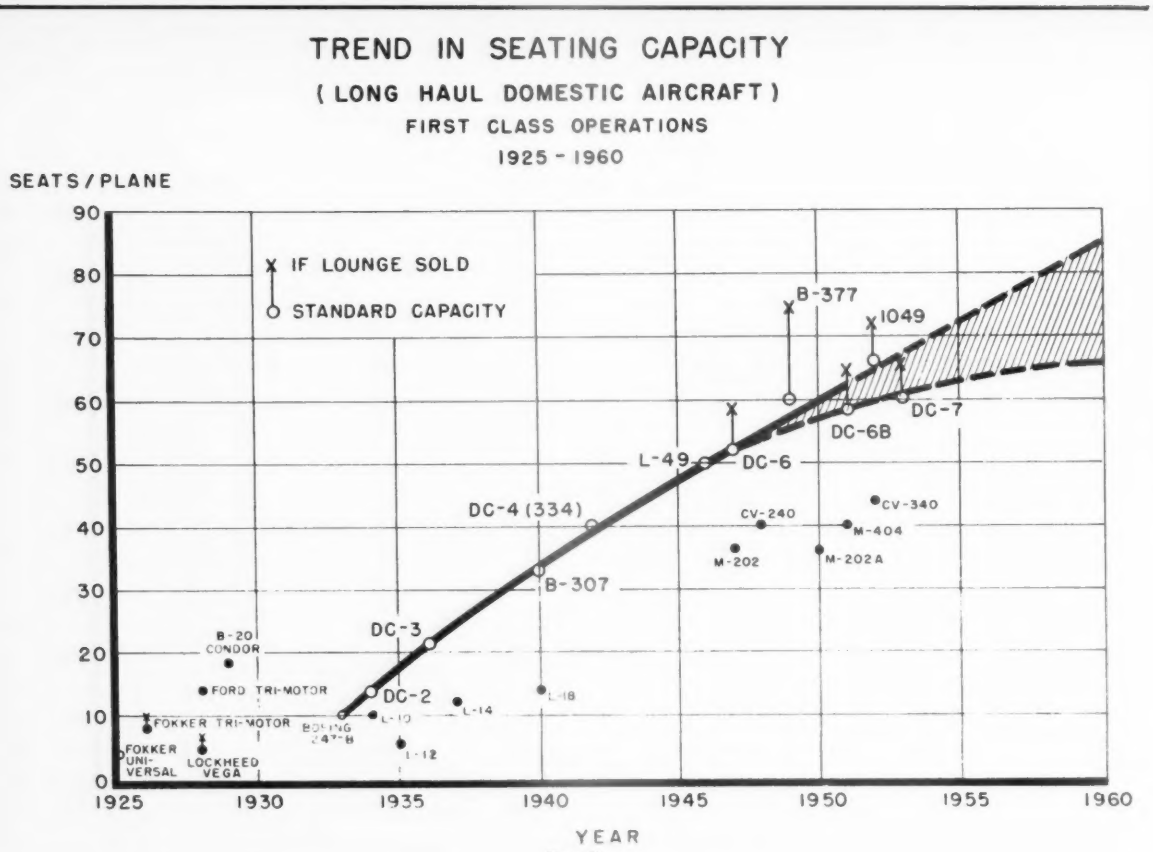


FIG. 7.

The third turbine-powered airplane on which the British are placing great hopes is the four-engined turboprop Bristol Brittannia. This is a relatively large (Constellation 1049E or DC-7 size) airplane capable of transatlantic operation at speeds about the same as the Constellation 1049E or DC-7 airplanes. The Brittannia is in development flight test now and is expected to enter service on B.O.A.C. before too long. It is as yet too early to say what the Brittannia's role will be, but it shows promise of speed, comfort, range, and economy which would permit it to be successful, assuming no critical detail problems appear in service.

This then is the group of British transports competing with the United States for the world market. The British are dead serious about taking the world market, and the British aircraft industry is being wholeheartedly backed by the British government in this endeavor.

The next move is up to the United States. As can be gathered, the key to any turbine-transport development lies in the availability of suitable power plants. During the latter part of World War II, the United States started building some jet engines under license arrangements with the British. Since the war, additional license agreements have been made between U.S. and British companies. Immediately after the war the U.S. companies also started independent engine developments. This combined effort has now finally brought the U.S. engine companies to the place where they have under development turbine-type engines of power, fuel consumption, and dependability characteristics capable of meeting the standards and requirements of the U.S. air-transport industry. Thus the groundwork is laid for the next type of long-range high-speed transports by the U.S. aircraft manufacturers.

Boeing has already announced that it is proceeding with the construction of its Model 707 (Project X) four-engined jet transport and combat aircraft refueler. It is expected that this airplane will carry 80 passengers at 500 m.p.h. (or over) at high altitude for long range. First flight is expected late in 1954, and air-line service could be expected late in 1956 or in 1957. At this writing there are no reported firm orders for the Boeing Model 707.

Convair has stated that its main interest is in turboprops and has announced that it will have conversion kits for Model 340's.

Lockheed and Douglas, the primary long-range transports manufacturers of the postwar period, are not talking yet, but we can be assured that they are not ready to give up their present commanding position in the transport field. With no Government subsidy to cover prototype development and to underwrite initial production, the monetary risks are tremendous in the

development of these new jets, so it is evident that Lockheed and Douglas are seriously studying the overall business problems of the introduction of these new transports; the results of failure to secure a sizable market could be very serious for the manufacturer.

The foregoing historical résumé has been rather involved, but so has been the development of air transport. Statics are dull, but a few are in order to give scale to air-transport development through the years. Data for the United States scheduled air lines are, in general, the only ones available, so the statistical curves cover these data only. Presented are plots of the statistics vs. time, covering the following: Fig. 1. Revenue passenger-miles per year. Fig. 2. Revenue cargo ton-miles per year. Fig. 3. Passenger-miles per fatality. Fig. 4. Average fare per passenger-mile. Fig. 5. Average revenue per cargo ton-mile. Fig. 6. Cruising speed of models as introduced. Fig. 7. Passenger capacity of models as introduced.

The trends discernible from the above discussion and statistics may be summarized as follows:

(1) Air-traffic growth is tremendous, having averaged 26 per cent per year for the last 20 years. There appears to be a slight tendency toward leveling off.

(2) Air-transport safety continues to improve. This is a primary factor in the whole transport picture, and any new transports must be designed to continue this trend.

(3) Average fare in real dollars continues to decrease, as it must for traffic growth. Direct operating costs of new models have also continually decreased, as they must to permit continued fare reduction, together with profitable operation.

(4) Cruising speed, altitude range, and capacity of transports have progressively increased. With increasing traffic and new power-plant developments, these trends should also continue.

(5) Air cargo, starting after World War II, has grown rapidly, and rates have progressively been reduced. As transports are developed with greater efficiency, the trends are for continued rapid growth of air cargo.

(6) The start of helicopter mail service commercially, and the rapid growth of helicopter use militarily in Korea, following the early history of transport airplanes, portends a trend toward the use of the helicopter in short-range commercial air transport.

(7) Development of suitable turbine engines makes possible continuation of the transport trend to higher speeds and altitudes, with the possibilities of longer range and lower operating costs. The trend appears to be toward jet transports for medium- to long-range service and possibly to turboprop transports for shorter ranges.

The first 50 years of powered flight have seen the emergence of air transport as a valuable adjunct to world communications, capable of economic self sufficiency and one of the world's great industries. Trends point to continued healthy growth toward a more useful, safer, more economical, and greater air-transport industry. This is the dedicated purpose of the thousands of men and women who design, build, and operate the world's transport airplanes.

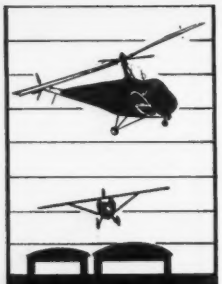
Special IAS Publications

	Member Rate	Nonmember Rate
Aeronautical Engineering Index – 1952	$ 3.00	$ 5.00*
1951	2.50	4.00*
1950, 1949, 1948, 1947 (each)	2.00	3.00*
Second International Aeronautical Conference Proceedings	15.00	17.50*
First Convertible Aircraft Congress Proceedings	3.00	5.00*
Second Convertible Aircraft Congress Proceedings	3.00	5.00*
Sixteenth Wright Brothers Lecture—Technical Trends in Air Transport, William Littlewood (Reprinted from the April, 1953, JOURNAL OF THE AERONAUTICAL SCIENCES)	1.00	1.50
The Earth's Atmosphere, H. E. Roberts, including 20- by 16-in. colored chart (Reprinted from the October, 1949, AERONAUTICAL ENGINEERING REVIEW)	0.65	1.00
Index to Books on Selected Technical Subjects in the IAS Library (up to 1950), unbound	2.00	2.00*
"Fifty Years of Flight"—A Chronicle of the Aviation Industry in America, 1903–1953, Welman A. Shrader (Published by Eaton Manufacturing Company. Reprinting and Distribution Rights Granted to IAS)	4.50	5.00

*Add $1.00 for orders outside the U.S.A.

These may be obtained by writing to

Publications Department, Institute of the Aeronautical Sciences, Inc., 2 E. 64th St., New York 21, N.Y.



GENERAL AVIATION

Design Trends in 50 Years—Civil Aviation Other Than Transport

By T. P. Wright

U.S. Naval Aviation, 1918–1921. Curtiss-Wright Corp., 1921–World War II, entering as Exec. Engr. and leaving as V.P. and Dir. of Engrg. World War II, Recorder-Member, APB, and Dir., ARCO. CAA Adminis., 1944–1948. V.P. for Research, Cornell U., since 1948. Also, Pres., Cornell Aero. Lab., Inc.

IN WRITING OF THE DEVELOPMENT of nontransport civil aviation in the United States during the 50 years since December 17, 1903, when Orville Wright could wire his father, "Success four flights Thursday morning . . . ," one is tempted to reflect not only on the subsequent progress and development of uses for the airplane but also on the many years of groping to solve the problems of human flight which had preceded. The aspirations to fly and the strivings to achieve flight are brought to mind by many names: Icarus, who in mythology flew too near the sun which disastrously melted his waxen wings; Leonardo da Vinci, whose 15th century sketches of helicopters long awaited further attention; and in the 19th century, Henson, Cayley, Stringfellow, and Langley in their concepts of powered flight; and, in gliding achievements, Montgomery, Lillienthal, Chanute, and the Wright brothers themselves. In some there was inventiveness, in some there was scientific research with purposeful investigation and experimentation, and in some there was merely an urgent desire to succeed and tireless effort. But in no others were all these qualities combined: full honor to the Wright brothers!

I will deal here with powered flight of heavier-than-air piloted vehicles and that group of uses not included under the headings, Military, Naval, and Civil Transport—i.e., nontransport or general civil aviation. I will touch upon development and design trends, uses within this field, progress in achieving importance and some indications of where we may be headed.

USES

In Table 1 there appear the categories of use to which civil aircraft are put and the percentage and resultant number existing in each classification at present. Within each group there are many subdivisions and in some a wide range of sizes. But generally speaking, we are considering the small plane of less than 3,500 lbs. gross weight, powered by one engine, recognizing however that the twin-engined aircraft with gross weights up to 5,500 lbs. is finding increasing demand in certain fields, particularly business, wherein also many large transport planes are utilized.

These figures are derived from CAA surveys conducted in 1952, modified slightly to allow for indicated trends in 1953, and rounded off. A few notes on what each group includes are given below:

Business, the largest category representing about one-third of the total of nontransport civil aircraft, includes planes owned or used by corporations and executives and used as a tool in business operations. Here all sizes are included ranging from Cubs to DC-6's, with a majority, however, in the four-place single-engined class.

TABLE 1

Use	Civil Aircraft, %	Number	Nontransport Only, %
Business	19.5	17,550	32.8
Instructional	11.0	9,900	18.5
Sport	10.5	9,450	17.6
Farmers	7.5	6,750	12.6
Industrial	7.0	6,300	11.8
Transportation for hire	4.0	3,600	6.7
Subtotal	59.5	53,550	100.0
Air carrier	1.7	1,530	
Inactive	38.8	34,920	
Total	100.0	90,000	

Also noteworthy is the fact that these planes are, in general, flown by pilots having commercial flight certificates. Included are the 1.0 per cent of aircraft (about 900) used by Federal, State, or Local Government agencies. This business use of the airplane has grown by leaps and bounds since World War II and is continuing to expand.

Instructional and training use, next in order, is self-defining and, since the boom years immediately following the war, has decreased in relative position.

Sport or pleasure use—the personal aircraft, which the enthusiasts at recurring intervals have envisioned as the most important category, has not realized the hoped-for place in our scheme of things for a number of reasons described later. Family use of the airplane is relatively small, but its potential is the greatest of all.

Farmers, however, have continued to find the airplane an attractive and useful adjunct to their operations, and there has been a steady increase in this category. As presented in Table 1, this heading refers to personal ownership by farmers and ranchers and does not include commercial operations in performance of agricultural services. Were such agricultural uses to be extracted from the following item (industrial) and combined with those of farmers, we would find agricultural utilization to represent 22 per cent of the total, second place in the table for nontransport aircraft.

Industrial uses are many indeed. A partial list includes: seeding, dusting, and fertilizing in agriculture; aerial photography for many purposes; spotting operations, such as fish and forest fires; patrolling and inspection activities; and prospecting, ambulance services, and aerial advertising. This also is a growing field.

Transportation for hire includes charter flying and taxi services, becoming increasingly important to the executive as a travel means supplementary to scheduled air carrier transportation. Such services, which get one quickly to places off air lines or off single air-line systems and does this exactly when the service is needed, are proving so increasingly convenient as to cause an expanding demand.

In each of the above categories there is included the appropriate proportion of U.S. Aircraft operating outside the United States, about 1 per cent or 900 in all.

For considering trends the most important single point to note from the above is the expanding utilization where professional pilots perform the flying function and the generally unrealized usefulness experienced by pilots with private rating.

Trends in Configuration and Characteristics Since 1903

In the following discussion I will describe and illustrate by pictures the changes in appearance and the advances in speed of U.S. Aircraft in 50 years, dividing the period into five decades. Although each decade is described in terms of the typical or average development of the period, naturally there are many overlappings and a few anticipations. Also, particularly during the past two decades, the uses have become so diversified as to require description by classes of use, size, or performance categories. The advantages, however, for this broad stroke procedure in a paper having severe restrictions on length and number of illustrations permitted are compelling.

1903–1913.—This first decade started out from scratch with the Wright brothers original flying machine presaging what might be expected for some time thereafter. This plane, indeed, serves well as an example of the type of aircraft appearing during the period. Throughout these first 10 years, the pusher biplane predominated. The pilot, together, in a few instances, with his passenger, was located on an open framework, with no fuselage to house crew or equipment. Horsepowers during that period ranged from the 12 of the original plane, to 50. Speeds ranged from 30 m.p.h. to 50, with little difference between the maximum and minimum speeds attainable in any one model.

Although there were a few innovations in arrangement tried out, ranging from monoplanes to multiplane configurations, none was outstandingly successful in this country, which prompts me to select the Wright brothers plane of 1909 as typical of the period. The accompanying photograph, Fig. 1, is therefore shown for this purpose. This plane was powered by a Wright brothers engine giving about 25 hp., almost double that of the 1903 engine. Its speed was 42 m.p.h. compared with 30 of the original flying machine. It will be noted that the pilot is in a sitting posture rather than prone.

FIG. 1. The 1909 Wright Flying Machine. Characteristic of the first decade of human flight.

FIG. 2. The Curtiss JN-4 "Jenny." Characteristic of the second decade of flight.

FIG. 3. The Waco 10. A good example of the biplane of the mid-1920's in the third decade of flight.

FIG. 4. The Curtiss Robin. An example of the externally braced cabin monoplane of the third decade of flight.

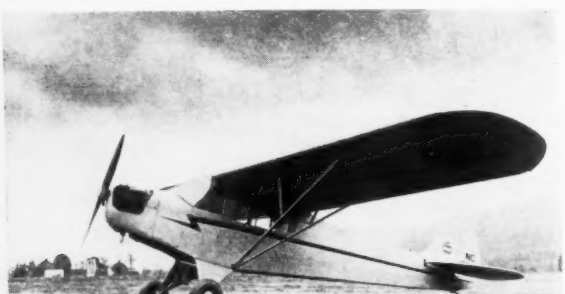


FIG. 5. The Piper J3 Cub. A "best seller" of the fourth decade of flight.

1913–1923.—The typical plane of this second decade incorporated a major change in configuration. For the most part, aircraft of the period of the first World War and a few years thereafter, were of the tractor biplane arrangement with a covered fuselage and open cockpits in which usually two persons sat.

The horsepowers ranged from 50 to 100 and the speeds from 50 to 90 m.p.h. Toward the end of the period, an innovation was introduced in the form of the externally braced monoplane, represented by the Loening M-80 Air Yacht. Selected to show the typical plane of this second decade is the Curtiss JN-4D, powered by the OX5 water-cooled, 90 hp. motor, illustrated in Fig. 2. Its speed was about 75 m.p.h. Not only does the "Jenny" typify the period, but it was also the plane that enjoyed the largest production and in which a great many pilots, both during the war and subsequently, received their training.

1923–1933.—During this third period there were two configurations that were constructed in fairly equal numbers. One was the tractor biplane, which with refinements continued the type of aircraft typical of the preceding decade. The other was the high-wing externally braced monoplane. Diversity of size and use makes it difficult to state any single range of horsepowers or speeds as typical of the period, but possibly we could state that horsepowers were from 65 to 110 for the two- and three-place planes, with accompanying speeds ranging from 90 to 135 m.p.h. In the four-place aircraft, the horsepowers were considerably greater, from 150 to 300. Speeds, however, ran from 100 to 150 m.p.h.

In the case of the externally braced monoplane, the enclosed cabin configuration became popular. Toward the end of the period there were one or two internally braced low-wing monoplanes brought out; nevertheless, it was not until the subsequent decade that this configuration came into its own.

Whereas, in the first and second decades, the water-cooled engine was used almost exclusively, we find in this third decade the advent and extensive use of the radial air-cooled engine.

Selected as typical of the period is the Waco 10 Biplane, Fig. 3, powered by an OX5 motor and having a speed of 96 m.p.h.; and the Curtiss Robin, Fig. 4, with Challenger 170-hp. engine and making 120 m.p.h. top speed. The Ryan Monoplane was also typical of the period, and Colonel Lindbergh's first solo transatlantic flight in the "Spirit of St. Louis" was the spark that created the flaming enthusiasm for personal flying which typified the end of the decade up to the time of the depression.

1933–1943.—The arrangement that typifies another major change in configuration was the internally braced low-wing monoplane which appeared so extensively in this fourth decade. There was, however, a continuation in approximately equal numbers of the externally braced high-wing monoplane, but with a definite reduction, which toward the end of the period was to the vanishing point, of the biplane. The planes ranged

from two- to five-place and horsepowers from 60 to 125, with speeds of 80 to 125 m.p.h. for the two and three seaters, and from 140 to 200 m.p.h., with engines of horsepowers of 145 to 450, for the planes of the larger seating capacities. There were many notable designs created during the period, which, but for space limitations, would be shown. However, I have selected for illustration one small high-wing externally braced model that exceeded all others in numbers produced—the Piper Cub, Fig. 5. With a 50-hp. Continental engine, this plane could fly at about 90 m.p.h. Also shown, to illustrate the low-wing internally braced type, is the Ercoupe, Fig. 6. A speed of 117 m.p.h. could be achieved when powered by a 65-hp. Continental engine. Noteworthy in this case, is the use of the all-metal monocoque type of construction with side-by-side seating.

A change in engines also took place, for, although the radial air-cooled engine continued to be used extensively, there now appeared the in-line and particularly the horizontally opposed air-cooled motor. By this time, the water-cooled engine had almost completely disappeared from the scene.

It was toward the end of this period that there occurred a tremendous innovation, the advent of the helicopter, invented and successfully flown by Igor Sikorsky. This superseded the earlier autogyro configuration for rotary-wing aircraft whose potentiality was far less than the helicopter in the particular characteristics for which these types excelled—i.e., capability of rising and descending vertically.

1943–1953.—Continuing into the present period, the fifth decade of flight, there are many fine examples of the externally braced high-wing monoplane, although the trend is somewhat toward the internally braced low-wing configuration. Horsepower outputs are available in present-day engines from 60 to 225, and, of course, even more in some instances for special purposes. When powered by engines in the range cited, speeds of 100 to 190 m.p.h. are attained.

Selected as typical of the period is the four-place high-wing Cessna 180, Fig. 7, capable of 165 m.p.h. when equipped with a 225-hp. Continental engine, and the four-place low-wing Beech Bonanza, Fig. 8, with a top speed of 190 m.p.h. when powered by a 185-hp. Continental engine.

Recently, a number of twin-engined aircraft designed especially for company uses have appeared. Carrying six to eight persons and having speed capabilities of the order of 225 m.p.h., they will surely command an expanding market.

Also shown is a view of the Sikorsky S-55 helicopter, Fig. 9, as a portent of what may be the type selected for substantial use in the future, where its special capabilities permit important timesaving by eliminating or reducing time consumed in ground travel from airports farther from centers of population than its own rooftop or vacant lot heliports. This aircraft is powered by a Pratt & Whitney Wasp engine of 600 hp. and has a top speed of 110 m.p.h.

Again one should emphasize the broad range of uses for nontransport civil aircraft. This has resulted in the development of special configurations designed best to suit each purpose.

Development of Design

Yardsticks to Judge Aeronautical Progress.—Basically, advancement in aircraft design excellence can be achieved by improvements in three major areas—

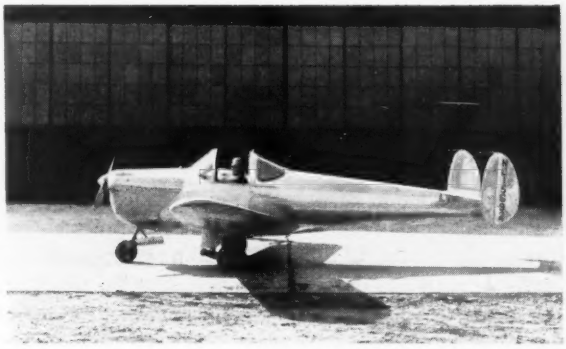


Fig. 6. The Ercoupe. An example of the all-metal fuselage, internally braced monoplane developed and widely used during the fourth decade of flight.

Fig. 7. The Cessna 180. Recently developed for the business executive field, a good example of the high-wing externally braced monoplane of the present decade of flight.

Fig. 8. The Beech Bonanza. A fine example of the fast executive aircraft and taxi plane of the present time, five decades since the Wright brothers' first flight.

FIG. 9. The Sikorsky S-55 Helicopter. Representative of the important development of rotary-wing aircraft to be reckoned with in many fields in the future.

namely, reduction of drag coefficient, increase of lift coefficient, and reduction of weight. Supplementing these, of course, is improved stability, control and general handling properties, together with the ever present need for simplified design from the standpoint of facilitating production and thereby reducing cost.

Several years ago, Jack Northrop, in an address in Washington sponsored by the National Air Council and the Library of Congress, developed a table to indicate aerodynamic efficiency improvement, utilizing maximum lift, minimum drag, and the ratio of the two as yardsticks. As a further indication of the importance of drag reduction, he compared the power necessary to drive aircraft of various vintages through the air at the same speed, on assumption of similar size, while retaining the drag coefficient of the original machine. In Table 2, I have employed this same general scheme applied to the typical aircraft of the five decades previously described, with the addition of a further criterion to show improved structural design from the standpoint of weight reduction given as the ratio of useful load to gross weight. Power required at 150 m.p.h. per 1,000 lbs. useful load, as a measure of overall efficiency, is given in column 11.

Table 2 may therefore be used as a gage for judging what has been accomplished basically design-wise during the 50 years of flight.

TABLE 2

When comparing the Beech Bonanza with the Wright brothers' plane, it will be seen that, although maximum lift coefficient during these 50 years has increased by approximately 40 per cent, drag at maximum speed has been reduced to a figure about one-fourth as large. As a result, the ratio of the two has improved sixfold. Ratio of useful load to gross weight has doubled during these 50 years. Power requirements to fly at 150 m.p.h. has decreased almost tenfold, and for such flight speed per 1,000 lbs. of useful load has decreased seventyfold, which dramatically demonstrates the tremendous gains attributable to design improvements, particularly the reduction in drag.

Design Changes

In studying the design innovations that were introduced during the development period of civil aircraft, it seems appropriate to consider the airplane as composed of five major units—namely, wings, fuselage, control surfaces, landing gear, and power plant. In the following discussion, therefore, I will take up each of these and give a brief indication of aerodynamic and structural features that characterized successive changes.

Wings.—There was a gradual change from the very thin highly cambered upper and lower wing surface of the Wright brothers' plane to thicker surfaces culminating in the common use of the Clark-Y section of the 1920's. This was superseded by airfoils of the NACA low-drag type, modified in varying degrees, as widely used at present. In the 1930's, flaps were added to increase lift and drag (during landing approach) to afford improved take-off and landing characteristics. With the advent of all-metal wings, smoothness of surface became prevalent, and more and more attention was given to its achievement. Parasite drag of all kinds was continuously reduced.

TABLE 2

1 Decade of Powered Flight	2 Year	3 Airplane	4 Max. Speed, M.p.h.	5 Horsepower	6 Max. C_L	7* C_D at Max. Speed	8 Max. C_L / C_D at Max. Speed	9† Brake Hp. Required at 150 M.p.h.	10 Useful Load / Gross Wt. (Per Cent)	11‡ Brake Hp. Required at 150 M.p.h. per 1,000 Lbs. of Useful Load
1	1903	Wright brothers	30	12	1.4	0.081	17.3	1,082	20	6,880
2	1917	Curtiss JN-4	75	90	1.44	0.053	27.2	542	25.5	1,205
3	1927	Waco 10	96	90	1.4	0.042	33.3	289	40	358
3	1929	Curtiss Robin	120	170	1.4	0.047	29.8	304	34.6	390
4	1941	Piper Cub	92	50	1.55	0.042	37.0	195	32.7	540
4	1941	Ercoupe	117	65	1.50	0.032	46.9	124	39	270
5	1953	Cessna 180	165	225	1.85	0.033	56.0	171	41.6	165
5	1953	Beech Bonanza	190	185	1.97	0.019	103.7	106	40	98

* C_D at maximum speed is used rather than minimum C_D because of the high induced drag in the early airplanes, requiring them to fly at high lift coefficients even though having light wing loadings.

† Brake horsepower rather than thrust horsepower is used so as to reflect improved propeller efficiency as well as reduced drag.

‡ Column 11 obtained by multiplying Column 9 by the ratio $1{,}000/W_u$, where W_u is the useful load of the airplane, in order to reduce all airplanes to a common denominator.

Structurally, the wing design advanced from wooden spars of rectangular section through the stage of the I beam and box beam. The wing contour was achieved by wooden ribs tacked and glued together, then it went through the stage of stamped metal ribs and welded steel structure. Doped fabric sewed and taped in place was used in all cases. The wing was a hand-made job. Succeeding this type of construction was the stressed-skin structure, using stringers and stiffeners for achievement of high panel strength in the aluminum-alloy wing covering. This type of construction, as now quite generally used, is more susceptible to economical production in large quantities.

Fuselage.—Starting with no fuselage at all in the Wright brothers' plane, we advanced, with the advent of the tractor power-plant arrangement, to a stick and wire fuselage, fabric covered. In a few instances in the second decade, veneer fuselages were seen. Succeeding this was the welded steel fuselage framework, still using a fabric covering. Into the 1920's, most fuselages had open cockpits for the pilot and passenger, which, toward the end of that period, was succeeded by enclosed cabins. Finally, we find the general adoption of the monocoque fuselage structure of curved cross section, streamlined for achievement of lower drag.

Control Surfaces.—In the Wright brothers' plane, we note the location of the stabilizing and elevating surface forward of the pilot with the rudders aft, interconnected with the lateral control provided by wing warping. Variations of this arrangement were seen during the first decade, succeeded in the second by the location of the tail surfaces together at the rear and with universal adoption of wing flap ailerons. At first the horizontal stabilizer was fixed in position. This, however, was succeeded by a movable stabilizer for the achievement of trim under different power and loading conditions. This adjustable stabilizer configuration was succeeded by the elevator tab for accomplishing the same purpose. At present, there is some tendency to go back to the adjustable stabilizer, although this is not found in many small civil aircraft. Throughout the period control surfaces were balanced in a variety of ways to achieve low stick forces as desired.

As to structure used in the control and stabilizing surfaces, practice in general followed that described above for the wing.

Landing Gear.—Starting with the Wright brothers' skids, we soon find the adoption of wheels in the landing gear, usually in the tricycle arrangement. With the change in configuration to the tractor biplane as the standard during the second period, we note the typical landing gear using two forward wheels mounted on an axle and with a tail skid located aft on the fuselage. The next innovations were the introduction of a tail wheel and the use of brakes on the main chassis wheels. Following this recently was the adoption of the retractable landing chassis; and then, finally, the reversion to the tricycle wheel arrangement. During the late 1940's, the concept of the so-called cross-wind landing gear using castering front wheels appeared, and this, with the introduction of additional innovations in its design, is being increasingly considered as desirable.

Power Plant.—During the first two decades, the type of water-cooled reciprocating power plant along the lines constructed by the Wrights was generally utilized but refined to the extent represented by the OX5 and the Hispano Suiza in the second decade. These water-cooled arrangements, particularly the OX5, persisted into the third period partly because of the tremendous World War I surplus that existed. However, in the 1920's, the radial air-cooled engine made its appearance and almost completely superseded all other types for a considerable time. In the early 1930's, substantial drag reduction was achieved by the extensive use of NACA cowling or in many cases the ring cowling installed over the radial cylinders. Then, also in that period, there appeared the in-line and opposed cylinder arrangement of air-cooled engine, which now predominate in the nontransport civil field.

Possibly the greatest boon to civil aviation that can be named is the increasing reliability of the power plant. At the present time, failures in the engine itself are infrequent, such power failures as do occur being largely in the fuel or oil system or accessories.

From the wide-tipped wooden propellers carved out by the Wright brothers, we advanced to metal-tipped wooden propellers refined in section to the point where the Clark-Y aerofoil shape was generally used. Plan forms were also refined. These early propellers were of the fixed-pitch type. Then in the 1930's, many metal propellers of aluminum alloy were produced, first, the fixed-pitch type; then the two-position adjustable-pitch configuration; and, finally, the variable-pitch arrangement controllable to give optimum efficiencies in the several flight régimes. Some steel propellers are found on civil aircraft, but generally speaking, the controllable-pitch propeller of aluminum alloy predominates.

Growth of Nontransport Civil Aviation

Growth trends can best be shown by graphs. Produced in Chart No. 1 are graphs of aircraft production and student pilot approvals plotted from 1927 to the present time. The presentation of these particular curves, drawn on the same chart, has been planned because of the interesting correlation that aircraft production and number of student pilot approvals seem to possess. One may note the boom in both set off by the Lindbergh flight and reaching its peak in 1929. There was then a marked drop during the depression, with gradual increase after 1935, reaching a second peak for each in 1940. This was brought to a halt by the restrictions against the production of civil aircraft during the war, with, however, a rise to unprecedented heights immediately after the war, reaching a peak in 1946 of 35,000 aircraft and almost 200,000 student pilots. (Attention is called to the difference in the applicable scales on the accompanying chart which read directly for aircraft produced but must be multiplied

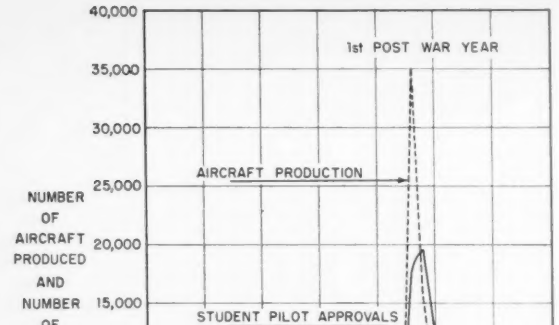


CHART No. 1. Civil Aviation (nontransport). Aircraft Production and Student Pilot Approvals.

by ten to obtain the number of student pilot approvals.) In the last year, there is a slight increase shown which it is believed will persist and rise gradually because of the real utilization achieved for civil aircraft in a number of nontransport fields.

The total number of registered aircraft and certificated pilots are shown on Chart No. 2. The figures for these graphs are, of course, controlled to a considerable extent by the production and student pilot figures of Chart No. 1. Thus, peaks in the latter will be reflected by higher points in the former so that by 1947 registered aircraft exceeded 90,000, and certificated pilots exceeded 400,000. The number of pilots has gradually increased to a figure of about 550,000 at the present time, although aircraft total has decreased slightly, meaning that attrition has exceeded production during the past 5 years.

On this same chart has been indicated the ratio of pilots to aircraft, which gradually rose from the 1 to 1 ratio in 1928 to a figure that apparently is stabilizing in the neighborhood of 6 to 1.

There are some lessons discernible from the study of these graphs. It would appear that economic conditions in the country, coupled with special factors brought about by wars, have played a significant role in determining aircraft production and civil interest in flying. However, other important factors are present, some of which will be described later, particularly the degree of safety and utility achieved. Characteristic of the period after the boom following the war was the drop in interest of owners evidenced by the extremely rapid turnover in ownership of aircraft coupled with widespread deactivation. (There are almost 35,000 of a total of 90,000 civil aircraft inactive at present.) Also, it should be noted that the large number of the aircraft certificated during the 1946 boom were used for training purposes and many of them were derived from war surplus. The prewar boom in student pilot approvals was brought about to a considerable extent by the Government-sponsored civil pilot training program; and in the postwar boom, student pilot figures were substantially increased by training acquired through the G.I. Bill of Rights.

Possibly the most encouraging factor that has been noted in the past year or two is the excellent utility that companies and executives have found in ownership and use of aircraft. It is believed that this will continue to increase. At the present time, company-owned aircraft exceed in number those used by scheduled air lines by a factor of 7 to 1, and even hours of flying and available seats for company-owned and executive planes exceed those flown by the scheduled air lines. There are now over 8,000 companies owning about 10,000 of their own aircraft, a figure that has risen by 33 per cent during the past year. Of these, approximately 1,700 use multiengined planes.

MISCELLANEOUS CONSIDERATIONS

In a paper dealing with the evolution and the accompanying design trends of the airplane, it appears appropriate to peer into the future and to evaluate probable, or at least possible, trends of the next decade or so. This will be done where appropriate in the following discussions of "Miscellaneous Considerations." The headings appearing below denote discussions pertaining to the aircraft itself and its components, together with others relating to qualities or outside factors that will effect design trends.

(1) *Special Configurations*

(*A*) *Helicopters.*—The importance of the advent of the helicopter to aviation must not be underestimated. It is still in an early stage of development, with constantly appearing innovations in configuration and

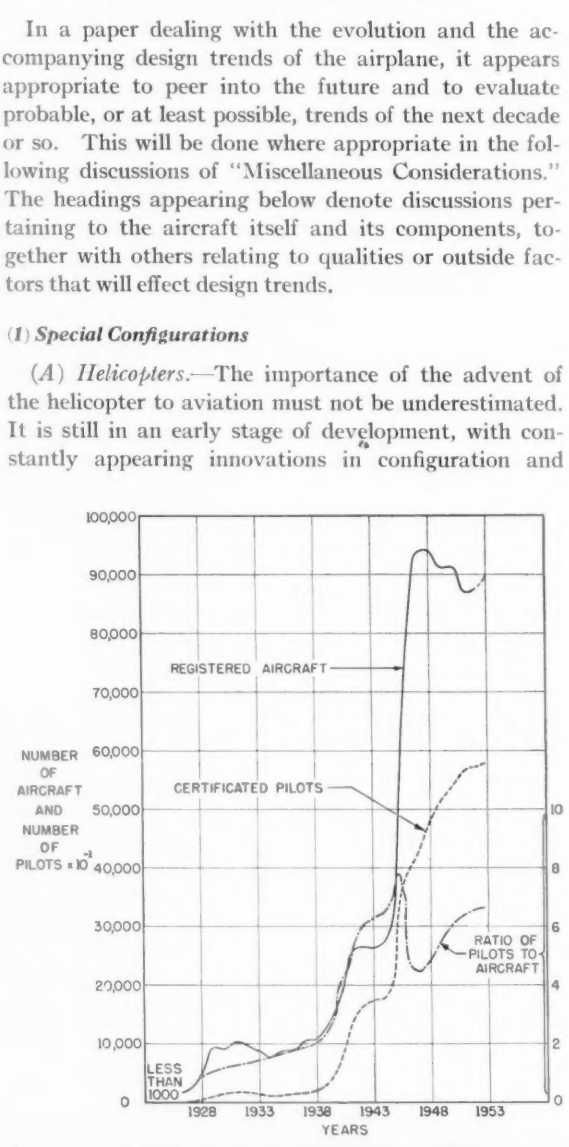


CHART No. 2. Civil aviation (nontransport). Registered Aircraft and Certificated Pilots.

other features. For instance, although the single-rotor arrangement with tail propeller to counteract torque predominates, nevertheless, there are many other configurations under development, including twin rotors laterally spaced with intermeshing blades, two concentric rotors, tandem arrangements, and others. The multiple uses for the helicopter in the Korean War have greatly accelerated development resulting in substantial production for both single-engined and twin-engined types.

Experiments are under way on power-plant installations, which in addition to the most generally used (transmission of power from a fuselage installed engine to the rotor) also include tip drives utilizing turbojet, pulse-jet, ram-jet, and pressure-jet (using air from fuselage installed compressor). Because of the elimination of torque reaction accompanying rotor tip drive, as well as for other reasons, there is much to recommend these schemes. Drawbacks are the high fuel consumption and the excessive noise, particularly in the case of the pulse-jet. However, one may not doubt the probability of an important place in the future for some tip drive arrangement on the helicopter rotor. Possibly a tip drive on a single blade, counterbalanced, will be found to have merit.

The areas of usefulness for the helicopter are many indeed, including all commercial uses, executive and company-owner services, utilization for taxi transportation, and possibly for personal use in sport and pleasure. As in the case of the fixed-wing aircraft, but to a greater degree, the question of pilot competence remains a doubtful factor when considering any general use by pilots having private pilot certificates.

(*B*) *Slow Landing Fixed-Wing Aircraft.*—Many believe that the fixed-wing airplane with high lift devices as inaugurated by the Curtiss Tanager, the winning design in the Guggenheim Safe Aircraft competition in 1929 and represented at present by the Helioplane, has prospects for greatly enhancing the usefulness of personal aircraft. With landing speeds of 30 m.p.h., this type of plane certainly lessens the need for emphasizing low competence of private pilots. Using the Helioplane as an example, there are other important features incorporated, including a geared engine with large diametered propeller for reducing noise and improved take-off; an engine exhaust muffler further reducing noise; landing-gear location well forward of the center of gravity, which also improves take-off and landing and prevents nose-over; the extensive use of wing flaps and slotted slats to get high lift coefficient and to assure stall- and spin-proof qualities; and the provision for unusually effective lateral control. An obvious possibility for this concept of plane is the use of boundary-layer control to obtain still higher lifts. Unfortunately, all of these provisions have made for a rather large airplane, and one that, if designed for very low landing speeds, may require more horsepower than the helicopter of equal load-carrying capability.

Desirable flying characteristics may thus be counteracted by higher costs and other disadvantages inherent in an airplane of relatively large size. Possibly, for the fixed-wing airplane, a landing speed for personal aircraft intermediate between the 30 m.p.h. attainable by use of these high lift devices on a plane of low-wing loading and the usual landing speeds of the order of 50 m.p.h. may prove most attractive. Nevertheless, the Helioplane design features have produced a safe plane of remarkably good characteristics for the use of the inexperienced pilot.

(*C*) *Convertiplane.*—This concept contemplates the incorporation of both fixed-wing and rotary-wing surfaces permitting the take-off, landing, and hovering capabilities of the helicopter, together with the higher cruising speeds possessed by the former. Certainly, such combination of characteristics is desirable and thus justifies the developments under way by military agencies. Following success in these, with however a substantial time lag, may come developments of importance in the nontransport civil fields.

There are, of course, potentialities for other configurations of vertical risers which are also receiving consideration in military circles at present.

(*D*) *Aero Car.*—The desirability of roadability for aircraft has been advanced as one method by which some of the difficulties encountered in bad weather conditions may be alleviated. One may asume the use of roadside landing strips on which personal aircraft could land when facing bad weather, proceeding on the journey by road after suitably folding or storing the wings. As in the case of the convertiplane, this design poses the troublesome problems always encountered when performing inherently difficult engineering tasks made more onerous by attempting to design for two purposes in the same vehicle. However, the advantages are so great that one would look for other roadable models to appear, in addition to the two or three now certificated.

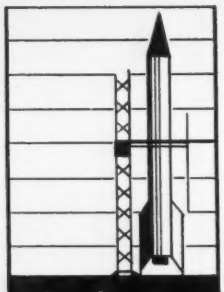
As well as reducing the cross-country delays when encountering bad weather, such an aircraft solves the problem of airport-to-city transportation when arriving at destination and provides ground transportation during stay in the city.

There should also be mentioned the future possibility for the roadable helicopter as distinguished from the roadable fixed-wing aircraft.

(2) *Power Plant*

One of the most encouraging factors for personal flying, applicable also of course to all others, is the great improvement in reliability of engines during the period of powered flight. Failures of engines themselves are few indeed, the major cause for forced landings being troubles in auxiliary systems or accessories. Nevertheless, for company uses, where seating capacity exceeds four or five, we find more and more twin-engined installations appearing on the market.

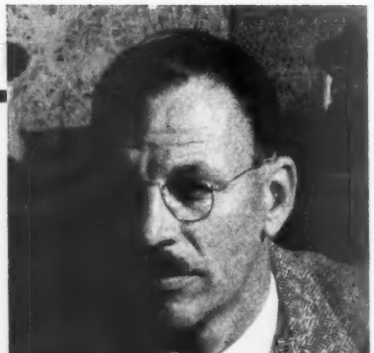
(*Continued on page 127*)



Design Trends—Guided Missiles

By Clark B. Millikan

Asst. Prof., 1928–1934; Assoc. Prof., 1934–1940; and Prof., Aero. Dept., Calif. Inst. of Tech., since 1940. Director, CalTech Wind Tunnel Testing, since 1935; S. Calif. Cooperative Wind Tunnel, since 1945; and Guggenheim Aero. Lab., since 1949. Chairman, Jet Propulsion Lab. Board.



THE TITLE ORIGINALLY SUGGESTED for this section of the REVIEW's commemorative issue was "Design Trends—Pilotless Aircraft." However, the alternative title given above was felt to be preferable for the following reason: The Guided Missile may be thought of as descended from two original forebears, the ballistic or artillery rocket and the manned aircraft. Certain present-day, moderate and long-range guided missiles exhibit clearly the predominant influence of the latter ancestor, and these are properly called pilotless aircraft. However, a much larger number, including some large and many small missiles, are much more closely related to the artillery rocket than to the airplane. Finally, in some cases the two original types of characteristics have been so interwoven as to produce a new synthesis in which it is almost impossible to say which of the two original ancestors had the predominant influence. The term "guided missile," which includes all of these types, is generally defined as an unmanned vehicle carrying a warhead or other pay load, propelled by an internally carried power plant and guided and controlled during its trajectory above the earth's surface to a selected target. The objectives of practically all guided missiles are military, and therefore current examples are almost universally subject to strict security regulations. Recently, a few general characteristics of some contemporary missiles have been released in the public press, but almost no design details are available. Accordingly, this paper will, of necessity, be largely historical in nature, in that examples of design problems and solutions will have to be chosen from past and essentially obsolete weapons. Current solutions can be discussed only in very general terms. However, even with these limitations, it is hoped that some idea can be given of certain of the major trends and their implications for the future.

The first line of development, that which stems from the ballistic rocket, has a long history beginning with the first recorded use of rockets in a military operation by the Chinese in 1232 A.D. These rockets were propelled by gunpowder, which had apparently been discovered shortly before. Like many present-day fireworks rockets, they were stabilized by a long trailing stick rather than by fins, and their primary purpose seems to have been incendiary. Knowledge and occasional use of rockets were extended to Europe by way of India in a remarkably short time. Primitive guns were apparently invented about 1313, and for some time these two artillery-type weapons developed in competition with one another. Progress with guns was, however, more rapid, and the rocket was soon essentially eliminated as a weapon in Europe.

Near the end of the eighteenth century, during a military campaign in India, British troops suffered badly

from the massed fire of rockets launched by rocket corps of several thousand men attached to the Indian army. The reports of these actions stimulated Sir William Congreve to undertake a serious rocket development program which was supported by the British government. By 1817 he had developed a complete family of rockets having ranges of 2,000 to 3,000 yards and carrying all the types of artillery ammunition then in use, with the exception of cannon balls. Rocket batteries were introduced into most European armies, and Congreve believed that they would replace and eliminate conventional artillery. However, the converse actually transpired for at least a century. The difficulty was that guns were still primitive and had potential for vast improvement, while Congreve's rockets gave nearly the maximum performance that could be obtained with black-powder propellant and the clumsy trailing stick stabilization. Radical developments in propulsion and aerodynamics were required if the rocket was to compete with rapidly improving artillery, and these developments did not occur for another century. One exception to this statement introduces the first significant contribution to rocketry to come from the United States. About 1850 William Hale discovered a method of stabilizing which permitted the elimination of the awkward and heavy trailing stick. This involved the introduction of twisted vanes in the rocket jet which imparted a spin to the rocket, like that of a rifle bullet or shell. These predecessors of the "spinner rockets" of World War II were used by the U.S. Army in the war with Mexico. However, the tremendous improvements in various types of guns and gun-launched missiles drove the rocket out of military use about the middle of the last century. It reappeared as an important element in the military arsenal only during World War II.

It was not until the twentieth century that serious interest in, and development of, rockets was reinitiated. Numerous individuals and small groups working quite independently of one another became interested in space flight, where the only feasible type of power plant is the rocket. Elementary calculations indicated that far better propellants than the solid gunpowders then available would be essential. Accordingly, studies of liquid-propellant rockets with their much greater potential were undertaken. Two professors were primarily responsible for initiating this rejuvenation of rocketry on a sound scientific basis—Goddard in the United States and Oberth in Germany—and for many years each was entirely unaware of the other's work.

Dr. Robert H. Goddard, shortly after receiving his Ph.D. in Physics from Worcester Polytechnic Institute in 1911, began the studies and experiments on rockets which were continued until his death in 1945. He early realized the superior performance capabilities of liquid propellants and concentrated on the development of liquid rockets. His first paper, "A Method of Reaching Extreme Altitudes," was published by the Smithsonian Institution in 1919, and the world's first successful flight of a liquid-fueled rocket was his achievement in 1926. From 1930 to 1940, supported by the Daniel and Florence Guggenheim Foundation, he continued developing, improving, and scaling up a series of liquid rockets at a desert laboratory in New Mexico. He not only developed the propulsion system but also introduced stabilizing and control techniques that were utilized by others in later true guided missiles. For example, many of his rockets contained stabilizing gyroscopes that controlled the rocket orientation by actuating vanes in the exhaust jet. This was identical in principle with the system employed in the later German V-2.

Unfortunately, Goddard's work had almost no influence on his contemporaries, since he worked (in Willy Ley's words) in "enormous and unnecessary secrecy." Thus the World War II German and American guided missiles derived almost nothing from Goddard's truly fundamental achievements, whose real magnitude has only recently been appreciated.

The German rocket program, which culminated in the tremendous V-2 effort, followed an utterly different—almost diametrically opposite—pattern. In 1923 there appeared a book entitled *The Rocket into Interplanetary Space* by a then unknown young professor, H. Oberth. This was a sound and mathematical presentation of the thesis that by means of rocket propulsion machines could, in the near future, be constructed capable of carrying men out of the earth's atmosphere and eventually out of its effective gravitational field. A number of young space-travel enthusiasts were stimulated by the book, and in 1927 they formed the "Society for Space Travel," which Oberth joined. During the next few years the Society was involved in a number of fantastic projects, including rocket-driven automobiles and a movie entitled *By Rocket to the Moon*. In addition, however, Oberth produced a second sound theoretical book, *Road to Space Travel*, and the Society carried out experiments on liquid-propellant rocket motors. By 1930 the Society had nearly 1,000 members and some funds to continue experimenting. In 1931 the first liquid rocket flight in Europe was made, and this was followed by a number of others. Most were accomplished by a small group of enthusiasts who formed the working nucleus of the Society. Shortly thereafter the Nazis began to come to power, and in the resulting confusions and upheavals the Society rapidly disintegrated and finally died in 1933.

However, Germany had already begun rearming, and the Army had decided that the primitive rockets that had been developed had the potentialities of furnishing powerful military weapons. Accordingly, they initiated an ambitious development program under the technical direction of a group of the key men of the nearly defunct Society. Wernher von Braun was the leader of the group and remained in technical charge of the long-range rocket program until the German defeat brought it to an abrupt and catastrophic end. The program followed was, from the first, aimed at the objective of a long-range ballistic rocket with large warhead. The development proceeded in a logical stepwise

manner with a series of test vehicles of increasing size and performance. The first two, tested in the neighborhood of Berlin, were designated A-1 and A-2, were about 5 ft. long, and weighed some 300 lbs. During these tests it became apparent that a much larger and more isolated test area was required, and the famous Peenemunde station on the Baltic was authorized. This gigantic establishment was completed in 1938 at a cost of some 300,000,000 marks and ultimately had a staff of about 4,500 people, a large fraction of which were of professional level.

At Peenemunde hundreds of flights were made with the much larger test vehicles A-3 and A-5, 25 ft. long and weighing about 1,700 lbs. During these tests the first tactical vehicle was conceived, and preliminary design of the famous A-4 or V-2 was initiated. It was clear that the extrapolations required for this missile were so large and the problems so difficult that flight tests of small test vehicles could not alone ensure success. Accordingly, an elaborate program of fundamental studies and component development was undertaken. This included wind-tunnel tests at all speeds up to a Mach Number of about 4; combustion chamber and complete propulsive unit ground tests; development of pumps, valves, and complete hydraulic systems for exotic liquid propellants; ground studies of the guidance and control components and systems; invention and perfection of observation and data reduction techniques so that the maximum of information could be derived from flight tests; and countless other elements included in the complete missile system. This complex program required numerous elaborate ground installations for many of which there were no precedents to follow. Thus, supersonic wind tunnels, large rocket-motor test pits, electronic and mechanical laboratories, etc., had to be designed, built, calibrated, and put to use producing background information.

The V-2 has been described in great detail in a number of reports and articles.* Here only a few of the major characteristics will be recalled to give an idea of the magnitude and scope of the problems involved: The gross weight of the 46-ft. long missile was about 29,000 lbs., of which some 19,000 was propellant and 2,100 warhead. The maximum velocity of approximately 5,000 ft. per sec. was reached about 60 sec. after the take-off, as the propellant was exhausted. Maximum range was nearly 220 miles, although most of the tactical firings were at something under 200 miles. Control was by elevators at the trailing edge of the four stabilizing fins, combined with graphite vanes connected to the elevators and operating in the rocket jet. The guidance system was somewhat crude by present standards but was immune to jamming, since no radio was employed. Azimuth was accurately set before take-off, and it and roll attitude were held constant by gyros in an autopilot. The missile took off vertically and was rotated in pitch by the autopilot, following a preset program calculated to put the missile on the desired trajectory. Range was determined by cutting off the propellant supply to the motor at a predetermined velocity, measured by an ingenious integrating accelerometer. With this system the dispersion about the target impact point was of the order of 2 to 3 miles, so that the missile could only be used effectively on area targets.

The magnitude of the flight-test program required to develope this guided missile is impressive, particularly in view of the tremendous supporting effort on the ground. As has already been mentioned, hundreds of flights were made with the A-3 and A-5 test vehicles before the first flight of an A-4 was attempted in July, 1942. This turned out to be catastrophic: the rocket rose about 3 ft. and exploded, demolishing many of the test-area installations and killing a number of the test crew. The second and third attempts rose higher but again resulted in explosions. The fourth flight, in October, 1942, was successful, as was the fifth. The next dozen or so were almost all complete failures, and over 100 of these tremendous missiles were test-fired before Hitler, in June, 1943, ordered production of tactical versions to be undertaken. The first tactical missile was launched against London in September, 1944, and by the end of hostilities well over 3,000 had been fired against English and continental targets.

This brief outline of the development of the most successful guided missile until the end of World War II exhibits strikingly many of the factors that are still required for bringing a guided-missile system to tactical use. Among these are: a large team of enthusiastic scientists and engineers with continuity of membership in at least the central core from inception to completion of the project; a large-scale supporting effort involving much elaborate ground equipment; an extremely extensive flight-test program using many test vehicles and prototypes; and, perhaps most important, the placing of full responsibility and authority for the entire missile system with one executive group. These factors, especially the last, will be discussed again later in connection with the current U.S. program.

The V-2 was unquestionably the culmination, up to 1945, of the line of development stemming from the ballistic rocket. Turning to that which had its origin in piloted aircraft, it appears that during World War I and shortly afterward there were serious attempts in most major countries to add automatic control and non-manual guidance to more or less conventional aircraft. The first successful flights were apparently achieved by a British team under A. M. Low in 1916. The concept used in the British approach was to utilize an inherently stable air frame with control from the ground by an observer watching the aircraft and transmitting commands through a radio link. This development never led to operationally useful results, primarily because of the absence of an autopilot. However, many years later, target drone pilotless aircraft incorporating an autopilot were developed in England as in most other major countries.

* For example: "A Critical Review of German Long-Range Rocket Development" by W. G. N. Perring; *Jour. Roy. Aero. Soc.*, Vol. 50, p. 483, 1946.

During World War I, similar experiments were also undertaken in France and the United States, using Sperry gyroscopic autopilots for stabilization and control. In the French development, command signals were given from the ground by radio, while the most important American program, under the technical direction of C. F. Kettering and Elmer Sperry, did not utilize any radio link. Their concept involved maintaining a given heading by a gyro compass, holding altitude by means of a barometer, and determining distance flown by an "air-log." Before take-off all these devices were preset to bring the missile over the target, when the air-log gave a command for a dive to the ground. This was essentially the same system as was successfully employed by the German V-1 in World War II. During the first war, the Germans also experimented with pilotless aircraft, investigating both gyroscopic stabilization and radio control. However, none of the projects mentioned above led to operational missiles, and after the war support dwindled and all were eventually dropped.

During the next 20 years the problem was pursued sporadically and at a low level of financial support. Although target and robot planes were developed in most countries and some work was done on controlled bombs, no true guided missile emerged until World War II. There was, however, an important development in the propulsion field during this period, which led directly to the later V-1. Historically, its origins lay in the speculations of the Frenchman Lorin, who in 1913 gave the principles of what was later called the Lorin nozzle or ram-jet and prepared detailed designs for construction of such a power plant. The ram-jet converts chemical fuel energy into thrust without requiring any intermediary rotatory or oscillatory power. Its operation requires a fairly high speed, since the cycle depends upon compression resulting from forward speed of the engine. Fuel is injected and burned in this compressed air, which then expands, accelerates, and cools as it passes out through a tail nozzle. The ram-jet is an exceedingly simple and light power plant but has no thrust at zero speed, low efficiency (especially with regard to fuel consumption) at subsonic speeds, and high efficiency only at relatively high supersonic Mach Numbers. Lorin's invention was therefore far ahead of its time, and there were no practical applications until well after World War II.

However, the fact that the ram-jet is, in principle, extremely cheap and light makes it a natural power plant for a "one-shot" device like a guided missile, which, in operation, is normally destroyed at the end of its first flight. A German engineer, Paul Schmidt, who may or may not have been familiar with Lorin's work, considered this problem in the late 1920's and invented an engine similar to the ram-jet but differing in two important particulars. Flapper valves were installed at the intake that alternately opened to admit air and closed during combustion to force the exhaust gases out the tailpipe. The combustion was, therefore, intermittent instead of continuous, and the motor had to be carefully tuned to operate at a definite combustion frequency. The Schmidt tube or pulse-jet, as it has been called, gives a finite thrust at zero forward speed and has a relatively high efficiency at moderately high subsonic speeds. Schmidt's initial patent was taken out in 1930, and the motor was worked on experimentally and theoretically for the next decade. In 1940 the Argus Motor Company was charged with the production of the resulting power plant, and in 1941 the German Air Force ordered the Fieseler Aircraft Company to design and build a guided missile using the Argus motor as the power plant. After much development, the V-1 or "buzzbomb" resulted, of which many thousand were produced and used operationally. The V-1 was essentially a simple conventional monoplane whose guidance and control system was almost identical in principle with the U.S. Sperry development of World War I. The flight path and target dive were preset before take-off, directional and roll control were by compass and gyros, altitude control was by aneroid, and range was by air-log.

Some comparisons between the V-1 and V-2 are of interest. Both had about the same warhead pay load, range, and accuracy, and the missile reliability of the two was probably comparable, although the wartime V-2's were plagued by a rather high percentage of premature detonations as the missile re-entered the atmosphere. The V-2 cost was some three to five times the $10,000- to $15,000-unit figure for the V-1. On the other hand, the vulnerability to interception could not even be compared. The V-1 flew at about a 3,000 ft. altitude and a 400-m.p.h. speed without any possibility of jinking or evasive maneuvering. Even in World War II it was, accordingly, extremely vulnerable to fighter and antiaircraft attack. Actually about half of the V-1's sent against England were intercepted and destroyed in this way, and only about 5 per cent of the large number launched against Antwerp got through and exploded at the target. Both weapons were remarkable technical achievements, and both did much damage to the Allies. However, neither seriously affected the military outcome of the war. This was partly because of their somewhat inaccurate and unreliable characteristics resulting from being rushed into service before development was far enough along, partly because of tactical errors in their employment, and partly because they came too late, when allied bombings had already started the disintegration of the German production and transportation system.

The German V-1 and V-2 were the only guided missiles employed operationally during World War II in large numbers. There were, however, many others under active development during this period. In Germany alone it has been reliably estimated that some 130 different missiles were carried to varying degrees of completion. Particularly in the antiaircraft field a number of missiles had just about reached the operational stage when the war ended. Controlled bombs or "glide bombs" (not true guided missiles) were developed by England, Germany, and the U.S. and were

used in service to a limited extent by all three countries, in some cases with considerable effectiveness.

The development of the guided missile into a major element in the military arsenal has, however, only come during the last few years. In discussing this postwar period, only the U.S. program will be considered since it is by far the most extensive, at least this side of the Iron Curtain, and probably includes any significant elements that are within the present bounds of technical feasibility.

It has become customary to classify guided missiles in four operational categories: surface-to-surface (SSM), air-to-surface (ASM), surface-to-air (SAM), and air-to-air (AAM). Projects in these four categories have been sponsored by four agencies: Army Ordnance, Air Force, Navy Bureau of Aeronautics, and Navy Bureau of Ordnance. Each agency has had projects in two or more of the categories. The types of missile which have evolved in the various categories reflect in a natural way the historical background from which the weapon in question has evolved. The historical line is clear and straightforward in the air-to-surface and air-to-air categories. In the former, the present missiles have developed naturally from aircraft-carried bombs, through controlled bombs and glide bombs, to true air-borne and launched guided missiles carrying bomb- or torpedo-type warheads. In the air-to-air category, the development started with conventional gun-type aircraft ordnance and proceeded through ballistic unguided rockets, to small highly maneuverable guided missiles. In each of the other two categories, however, there have been dual lines of development, one stemming from conventional ordnance weapons and the other having airplane origins. One group of surface-to-air missiles primarily sponsored by ordnance agencies has been considered as extending the range and improving on the accuracy of antiaircraft artillery. These missiles follow the artillery rocket tradition. The other group has been thought of as furnishing an eventual replacement for manned interceptors, and its missiles have much more the characteristics of pilotless aircraft. There is a similar division in the surface-to-surface category, one line starting with artillery and aiming toward weapons of increased range and fire power for primarily tactical employment, and the other starting with the long-range bomber and aiming toward strategic weapons of increased performance and decreased vulnerability. Even in the case of the strategic weapon there are protagonists for both the ballistic rocket and pilotless aircraft, each maintaining the superiority of his concept for this job.

The "design trends" can most easily be discussed within the framework of a technical or component breakdown rather than within that of operational categories. However, the latter must be kept in mind for they furnish an essential background for the discussion. A convenient component or functional breakdown is one that considers propulsion, aerodynamics and structures (particularly with respect to overall configuration), and guidance and control. The warhead problem is a special one and will not be considered here.

There are currently three types of propulsion systems which are widely used for guided missiles: turbojet, ram-jet, and rocket. The pulse-jet has, in this country, been continued only in the Loon, an American version of the V-1, which has been successfully used for training purposes. The pulse-jet seems unlikely to play an important role in our future missile program. The turbojet furnishes the propulsive power for several surface-to-surface missiles of the pilotless aircraft type. However, in its present form it is efficient only at subsonic speeds and is a complicated and expensive power plant for a one-shot device. In view of the rapidly increasing effectiveness of antiaircraft defenses, it would seem that the days of the subsonic guided missile, for which evasive maneuvers are difficult, are likely to be numbered. For this and other reasons it is the writer's belief that the turbojet is not the power plant of the future insofar as guided missiles are concerned.

The ram-jet and rocket thus remain as the contenders for the role of future guided-missile propulsion, at least until some radically new type of power plant is invented. It would appear that both will continue to have their fields of usefulness. The rocket, with its much larger thrust per unit of frontal area but far greater propellant consumption would appear to be most suitable for short-range high-acceleration missiles, while the ram-jet, using atmospheric oxygen instead of an oxidizer carried with the missile, should be more appropriate for longer range applications. This is, in fact, the case for antiaircraft missiles where the requirement for great maneuverability and the nature of the target require that the flight path remain within a reasonably dense atmosphere. However, for moderate and long-range attacks on essentially stationary surface targets, a ballistic trajectory has a large portion of its length essentially outside the atmosphere where practically no energy is dissipated in frictional resistance and where the rocket motor functions best, while the ram-jet is inoperable. Thus for such missions it is not *a priori* evident which type of missile is better: the rocket-powered one with essentially ballistic trajectory, or that which flies with ram-jet power through the atmosphere having much of its flight path practicallly straight.

The choice of power plant has a profound effect on the overall missile configuration and, hence, on the structural and aerodynamic problems involved. As indicated above, the ram-jet-powered missile is apt to have a moderate to long range and to fly much of the time along a roughly straight flight path. This requires aerodynamic lift, and hence suggests wings. Because of the range involved, drag is important, and maneuverability requirements are apt to be only moderate. Accordingly, a mono-wing rather than a cruciform configuration is usually indicated. Thus the overall shape of the missile is apt to resemble that of a manned supersonic aircraft. At the other extreme is the long-range ballistic-type rocket. Here the maneuverability requirements are relatively small, and controls

must be effective both at extremely low speeds during launching and also at altitudes above any effective atmosphere. Thus some sort of jet control is required, and the external aerodynamic surfaces can be small. The configuration is apt to be like that of the V-2, with relatively small stabilizing and control surfaces at the rear, and the relationship to the unguided artillery rocket is usually very apparent.

For the short-range antiaircraft missile, whether air- or ground-launched, the requirements are very different. Time of flight is short so that drag is of secondary importance and maneuverability must be very great. Thus a cruciform arrangement of lifting and control surfaces is indicated. This type of configuration is not very closely related to either the conventional manned aircraft or to the artillery rocket, both of which have a wealth of experience behind them. It also introduces some of the most difficult purely aerodynamic problems that have been encountered in the guided-missile program. The vortices shed from a long slender body and from a forward set of cruciform surfaces result in a complicated and rapidly varying flow field downstream. There are thus large and variable interference effects on any surfaces at the rear, leading to extremely difficult stability and control problems that have not yet been fully solved in all cases.

Probably the most crucial future problem involving aerodynamics and structures will be that of aerodynamic heating. It is particularly serious for relatively long-range missiles, whether ram-jet-powered or of the ballistic rocket type. The former must fly for considerable periods at high supersonic Mach Numbers where stagnation temperatures are high and thermal equilibrium is attained. The former re-enter the atmosphere at supersonic or even hypersonic speeds where stagnation temperatures may be measured in tens of thousands of degrees. Even though the condition is a transient one of extremely short duration, it is obvious that it will lead to tremendous heat-transfer and structural difficulties. The high percentage of air bursts of the wartime V-2's have been attributed to such effects, which have become even severer with more modern high-performance missiles.

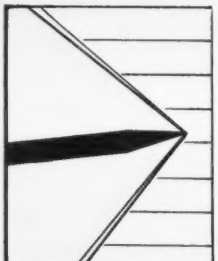
Turning, finally, to the field of guidance and control, the actual operation of control surfaces or other devices is accomplished, in practically all cases, by a servo system controlled by some sort of autopilot. The signals that are fed into the autopilot can be generated by any of a large number of different devices based on one of a bewildering variety of system concepts. Space here will permit only a brief outline of some of the more important of these guidance systems, together with a few comments on some of their respective advantages and disadvantages.

For maneuvering targets the "command system" is probably the simplest conceptually. Here the target location is continuously observed, as is that of the missile. Usually both observations are made from a single base station, but there may be two or more observation posts. Some sort of computer, not in the missile, then determines the path the missile should follow to intercept the target, and commands are sent by radio to the missile autopilot, which in turn causes the controls to be so operated that the missile maneuvers to the desired path. This system can, of course, also be used for nonmaneuvering targets. Its most elementary form, used with some relatively simple controlled bombs, employs visual observation of target and missile by an airborne bombadier whose brain serves as the computer. The commands resulting from his observations and estimates are sent to the missile by radio. More versatile, but also more complicated, systems for surface-to-air anti-aircraft missiles employ two radars, one tracking target and the other missile, with an electronic computer determining the optimum missile trajectory. The great advantage of this system is that no sensing or computing elements must be carried in the missile, which is, therefore, relatively simple and cheap. The elaborate tracking and computing gear is ground-based and can be used over and over again. The disadvantage is in traffic handling ability, since the tracking and computing equipment is pretty well occupied with a single target and missile from the time of launch until intercept or definite miss. Thus only a single target and missile can be handled at a time.

A second approach, requiring more guidance mechanism in the missile, is the so-called "beam-riding" system. Here a single radar tracks the target, and the missile is launched along the tracking beam at an appropriate instant. The missile contains sufficient guidance mechanism to keep it near the center of the beam where it must eventually intercept the target if the tracking is accurate and the available maneuverability is adequate. This system has somewhat better (although still limited) traffic handling capabilities, since only one radar is occupied with a single engagement and multiple missiles can be sent simultaneously against a single target to improve the kill probability. The greatest weakness lies in the fact that the missile is constrained to follow the unique trajectory given by the tracking radar beam, and this usually turns out to be an inefficient one from the points of view of time to target and fuel consumption.

The third system, which conceptually seems the most flexible and powerful, requires a homer or seeker in the missile. There are three types of homing guidance: active, semiactive, and passive. The first requires that the missile carry a complete radar set, both illuminating the target and receiving the reflected signals. The second utilizes an illuminating radar in the launching station (whether air-borne or ground-based) and requires only a receiving radar in the missile. The third utilizes some sort of radiation emitted by the target without outside illumination, together with a receiver in the missile which is sensitive to this radiation. The most common example of the passive type employs infrared as the radiation to be tracked. All three require more electronic and other gadgets in

(*Continued on page 129*)



Aerodynamics—Theory, Experiment, Application

By Hugh L. Dryden

With Bureau of Standards, 1918–1947: Chief of Aerodynamics Section, 1920; Chief of Mechanics and Sound Division, 1934; Assistant Director, 1946; Associate Director, 1946. With NACA since 1947: Director of Aeronautical Research, 1947; Director, 1949 to present.

WHILE AERONAUTICAL DEVELOPMENT is dependent on the contributions of many fields of science and engineering, aerodynamics plays a unique role. For it is the reaction between the air and bodies moving through it that makes propulsion and flight possible. There are applications of aerodynamics to other technical fields, but by comparison these constitute a small effort. The expanding effort to increase aerodynamic knowledge during the last 50 years has been stimulated by the needs of aeronautics.

Traditionally, aerodynamics is a branch of the science of mechanics, a part of classical physics, long antedating human flight. In the beginning it was primarily theoretical and mathematical in character. During the nineteenth century, some scientists and engineers concerned with ballistics and with the possibilities of mechanical flight began to make experiments. This knowledge stimulated the invention and development of devices to be used as component parts of flying machines.

Today the term aerodynamics is applied to this triplet of activities—theory, experiment, and application, which, starting as separate and almost distinct threads, are now thoroughly interwoven into the fabric of modern aerodynamics.

Theory Prior to World War I

The classical theory of the motion of a fluid without friction had developed as a mathematical discipline to a well-advanced state by 1900. The theory of a fluid with friction had been set forth and applied to a few relatively simple problems. However, the behavior of real fluids did not seem to fit either pattern, and hence these theories had no influence on the design of early airplanes.

As early as 1904 Prandtl set forth a theory of the motion of a fluid with small friction in which he considered the effect of the friction to be confined to a small region near the boundary, the remainder of the flow being governed by the classical theory of a frictionless fluid. He then showed that in the presence of a pressure increasing downstream a reversal of flow occurs within the boundary layer and the flow separates from the boundary. A small friction thus changes the flow pattern radically from that described by the classical theory. Except for a few theoretical studies by Prandtl's students at Göttingen, this important work remained almost unnoticed for nearly 25 years.

At about the same time Kutta and Joukowski showed that, while the classical theory of the frictionless fluid predicted no drag force in the streamwise direction, lift forces at right angles to the stream were consistent

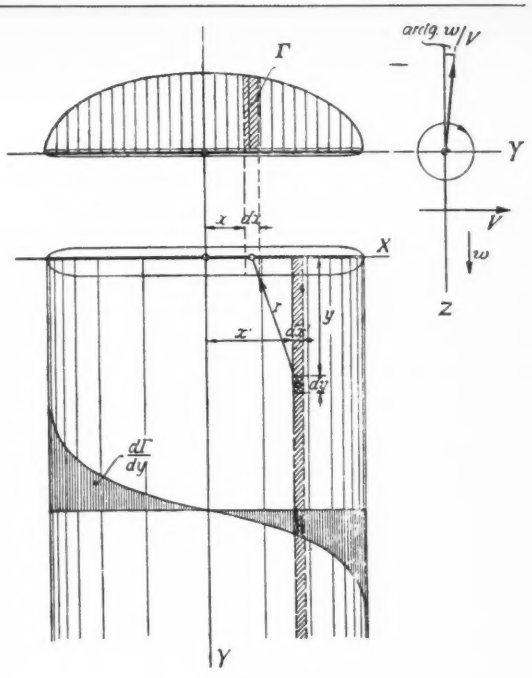
with the theory and were related to the circulatory component of the flow about the body. For wings with sharp trailing edges, the circulatory component could be determined by the condition that the local velocity should remain finite at the trailing edge, and the lift could be predicted.

Bènard and von Kármán developed a relation between eddy formations in a perfect fluid and the drag associated with separated flows.

Lanchester described qualitatively the flow about a finite wing, describing the formation of tip vortices, and the advantages of large aspect ratio.

In this period also, Lord Rayleigh applied the theory of similitude to aerodynamic problems. While this is not specifically aerodynamic theory, the extensive use of model tests and the description of their results in terms of nondimensional parameters made possible a much more rapid rate of progress.

Looking backward one can see theoretical developments that are now the cornerstone of rational design but which were then sterile so far as practical application is concerned. This was in part due to the meager experimental confirmation and the lack of contact and understanding between scientists and designers. But it is believed it was also a demonstration of the fact that technology must reach a certain state of development before a given theoretical advance can be utilized. Later this is seen in supersonic theory, which had limited application until aircraft and missiles attained supersonic speeds.



$$\mathbf{L} = \varrho V \int_a^b \Gamma dx,$$

$$\mathbf{D_i} = \varrho \int_a^b \Gamma w \, dx = \frac{\varrho}{4\pi} \int_a^b \int_a^b \Gamma(x) \frac{d\Gamma}{dx'} \cdot \frac{dx \, dx'}{x - x'}.$$

FIG. 2. Prandtl's formulas for lift, L, and drag, D_i, of a finite wing according to lifting-line theory.

FROM THE PRANDTL WING THEORY TO WORLD WAR II

At the beginning of the first World War Prandtl developed a theory of the flow of a frictionless fluid about airfoils of finite span. The Kutta-Joukowski theory for two-dimensional infinite-span wings had yielded a lift force but no drag. By contrast, Prandtl's theory of the finite wing yielded a drag force, to which the name "induced drag" was given by Munk. Prandtl independently of Lanchester's earlier qualitative description, had given mathematical expression to the strength of the trailing vortices from a finite wing, to the downward deflection of the finite mass of air passing near the wing which gives rise to a lift equal to the rate of imparting downward momentum, and to the drag that corresponds to the energy required to maintain this downward flow.

Prandtl's theory enabled prediction of the effects of aspect ratio, of biplane arrangement, and of optimum lift distribution along the span. Munk and other collaborators made wind-tunnel experiments that confirmed the theoretical results and brought the theory to the attention of German designers. By contrast with the boundary-layer theory of 1904, the experimental tools and techniques were now at hand. This synthesis of theory and experiment into experimentally proved design procedures marks the beginning of modern aerodynamics embodying rational theories supported by experiment.

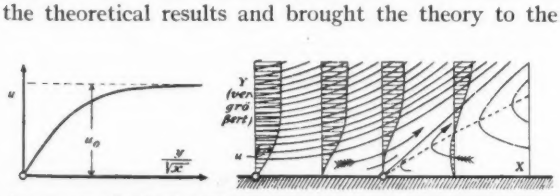


FIG. 1. Prandtl's first illustration of the boundary-layer concept and the phenomena of separation.

This great accomplishment of Prandtl and the Göttingen group was unknown outside Germany until 1921. Pistolesi described the work to Italian groups, the NACA in the United States published a summary paper specially written by Prandtl, and Roy in France and Glauert in England summarized Prandtl's work for their fellow countrymen. Additional papers and applications followed in every country. In addition, the work of Kutta and Joukowski on airfoil sections was extended by many workers. The thin airfoil theories of Munk and the methods of computation of Theodorsen are important milestones. The studies of the nonstationary lift problem by Theodorsen and Küssner represent extension to still another important area.

In the postwar period the application of the boundary-layer theory to the problem of profile drag received much additional attention. Experimental measurements demonstrated the physical reality of Prandtl's boundary layer. Transition in the boundary layer from laminar to turbulent flow received renewed theoretical attention, and the Göttingen school devoted itself

to extensive theoretical studies of the stability of laminar flow. Methods of predicting the separation of laminar boundary layers were developed. Empirical theories were advanced for turbulent boundary-layer flow and the prediction of turbulent skin friction. Space does not permit mention of all of the important contributions. Prandtl and von Kármán and their students and collaborators were most active in this field, but workers in many countries participated.

These developments in aeronautical theory were brought into sharp focus for the aircraft designer by Melvill Jones in 1923 in his paper on the streamline airplane. Jones computed the performance of an ideal

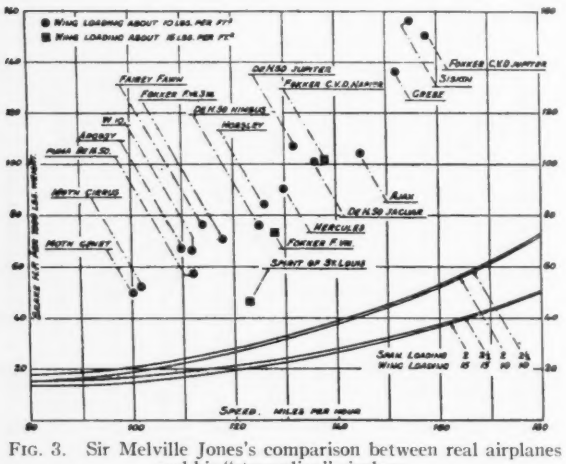


FIG. 3. Sir Melville Jones's comparison between real airplanes and his "streamline" airplane.

streamline airplane in which the drag was equal to the sum of the induced drag corresponding to the span loading of the airplane and the turbulent skin friction over the wetted area of the airplane. He compared this theoretical drag with that of the airplanes then flying. The graphic demonstration that existing airplanes had several times the drag of the ideal streamline airplane stimulated designers to realize the potential gains. Although the ideal seemed unattainable, it was approached in a comparatively few years, and today the goal has been set still higher—namely, that of reducing the drag to the sum of the induced drag and the laminar skin friction.

The period between the two World Wars may be characterized as a period of exploitation of rational theories of an incompressible fluid. The speeds of chief interest were considerably below the speed of sound. About the middle of the period propeller designers began to use propellers whose tips traveled at high subsonic or even supersonic speeds, and toward the end of the period diving airplanes encountered difficulties produced by the changing air reactions as the speed approached the speed of sound. Interest began to shift toward the supersonic region, although contributions to subsonic theory have not by any means ceased.

Compressibility Takes Over

The theoretical study of compressible flow problems began of course long before World War II. In the early part of the century we find such contributions as Prandtl's study of supersonic flow through nozzles (1904) and Meyer's analysis (1908) of a uniform two-dimensional supersonic flow deflected through an angle. Expansion around a corner takes place continuously, but compression against an inclined wall occurs through a shock wave. In the early twenties, ballistics problems of World War I and the propeller problem stimulated studies both at supersonic and high subsonic speeds. Glauert and Prandtl assumed that the flow around an airfoil could be considered as a small perturbation of a parallel flow, thus linearizing the equations. They derived the Prandtl-Glauert rule relating the compressible flow at high subsonic speeds to a corresponding incompressible flow. Ackeret developed a theory of the two-dimensional supersonic flow past a thin airfoil.

The following decade was more active. von Kármán and Moore gave an approximate theory of the flow about a slender body of revolution. Prandtl and Schlichting extended the incompressible airfoil theory to compressible flow. Taylor and Maccoll gave the exact solution for the supersonic flow past a cone with attached shock wave.

An important landmark was the Volta Congress of 1935 in Rome. Here, Busemann discussed the flow about three-dimensional wings and the benefits of sweepback for supersonic airfoils. This development was soon forgotten, since airplane speeds were still well below the speed of sound, and the idea was rediscovered for transonic applications by Betz in 1941 and independently by R. T. Jones in the U.S.A. in 1944. In 1941 Busemann presented a conical flow theory which has found extensive application. In 1946 R. T. Jones described a slender body theory and Puckett made systematic calculations of the drag of delta wings. By 1945 practical applications to supersonic missiles and the approach to supersonic speeds in piloted aircraft stimulated the rapid development of supersonic theory.

Some progress has been made in transonic flow theory. Notable are the development of transonic similarity relations and the advances made by von Kármán, Guderley, and Busemann.

At present, theoretical workers are active on many fronts, including hypersonic flow, low-density flow, and viscous compressible flow, to mention only a few. Their work is continually under scrutiny by experimenters and designers, and theory is playing an ever increasing role in design.

Early Experimental Tools and Techniques

Returning now to the second component of our modern aerodynamics, experiments to measure the force of the wind were a prominent feature of the latter part of the last century and the first decade of the present century. In a recent review G. A. Crocco

lists the methods used as railway and cableway experiments, ballistic measurements, whirling arms, observations of the flight of birds and insects, gliders launched from hilltops, freely falling bodies from the top of the Eiffel Tower, and wind tunnels. The results of most of the early experiments were not very reliable, and it is well known that the Wright brothers found the tables available to them seriously in error. The design of the Wright airplane was based in large part on measurements in a small wind-tunnel designed and built by them.

The principle of the wind tunnel was stated long ago by Leonardo da Vinci who said "What an object does against the motionless air, the same does the air moving against the object at rest." The principle was often contested during the last century, but certain experiments that seemed to contradict it were explained, when it was appreciated that the moving air stream must move at a uniform and constant speed over its whole cross section and the body must be small in comparison with the extent of the stream. These conditions were not met in the earliest wind tunnels.

The first wind tunnel of which I have record was designed by F. H. Wenham in 1871 for the Aeronautical Society of Great Britain. It was 18 in. square and 10 ft. long and had an air speed of about 14 m.p.h. At about the end of the century Zahm built a wind tunnel in which he measured the skin friction on flat plates with good accuracy. Riabouchinsky built a wind tunnel at Koutchino in 1904. Rapid development of the wind tunnel as an aeronautical tool began soon thereafter with the completion of Eiffel's first wind tunnel at Champ-de-Mars and Prandtl's first wind tunnel at Göttingen. Within the next 10 years the use of wind tunnels spread to all countries.

The earliest use of wind tunnels was for the empirical measurement of the lift and drag of aircraft wings, aircraft configurations, thrust and torque of propellers, and similar tasks. The usual balance was a three-component one measuring lift, drag, and pitching moment. The measurements were used to predict performance, static longitudinal stability, and control. The principles of the mechanics of a rigid body were applied to study the motion of airplanes using empirical wind-tunnel data for the forces and moments produced by the air. The work of Bryan on the stability of aircraft is especially noteworthy. Bairstow measured in a wind tunnel the stability derivatives required by the theory and de Havilland and Busk applied the results to the design and construction of an inherently stable airplane.

An early feature of wind-tunnel experimentation was the systematic study of wing shapes, plan forms, and monoplane and biplane arrangements. As already mentioned, this type of work was closely tied to theoretical developments beginning in the twenties.

Later Development of Wind Tunnels

Space does not permit more than mention of a few of the landmarks of wind-tunnel development. The importance of Reynolds Number was recognized very early. The variable density wind tunnel enabled the use of high Reynolds Numbers at less expense than otherwise possible. Special purpose wind tunnels such as the spin tunnel and free-flight tunnel were devised to meet special problems. When the importance of wind-tunnel turbulence was recognized, attention was given to the development of wind tunnels of very low turbulence. As aircraft speeds increased, wind-tunnel speeds were also increased, first in relatively small equipment with small drive motors, then in larger and more powerful equipment. Supersonic wind tunnels about 9 to 24 in. in diameter entered the scene about 15 years ago. Supersonic research has accelerated since the last war and especially since the first level flight of a piloted aircraft at supersonic speed in 1947. At present, five large supersonic wind tunnels are under construction in the United States, some of more than 200,000 hp.

Wind tunnels encountered difficulty near the speed of sound because of shock wave reflection and choking. To fill the gap other now familiar techniques were developed, particularly flight-test methods using rocket-

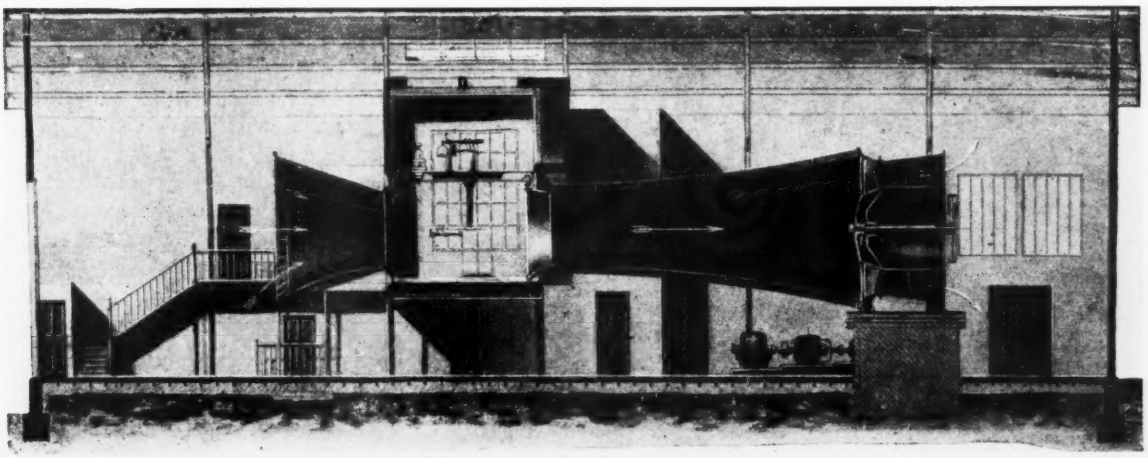


Fig. 4. Eiffel's wind tunnel at Auteuil completed in 1912.

FIG. 5. Construction progress on Ames unitary supersonic wind tunnel.

propelled models equipped with ratio telemeters to transmit data to a ground station and piloted airplanes designed solely to explore regions of speed and altitude beyond the capabilities of other airplanes. Both of these methods are currently in use and give information unattainable by other means, since the models or airplanes are in free flight. Within the past few years the technical obstacles to the use of wind tunnels at transonic speeds have been overcome, and many wind tunnels are in process of conversion to transonic operation.

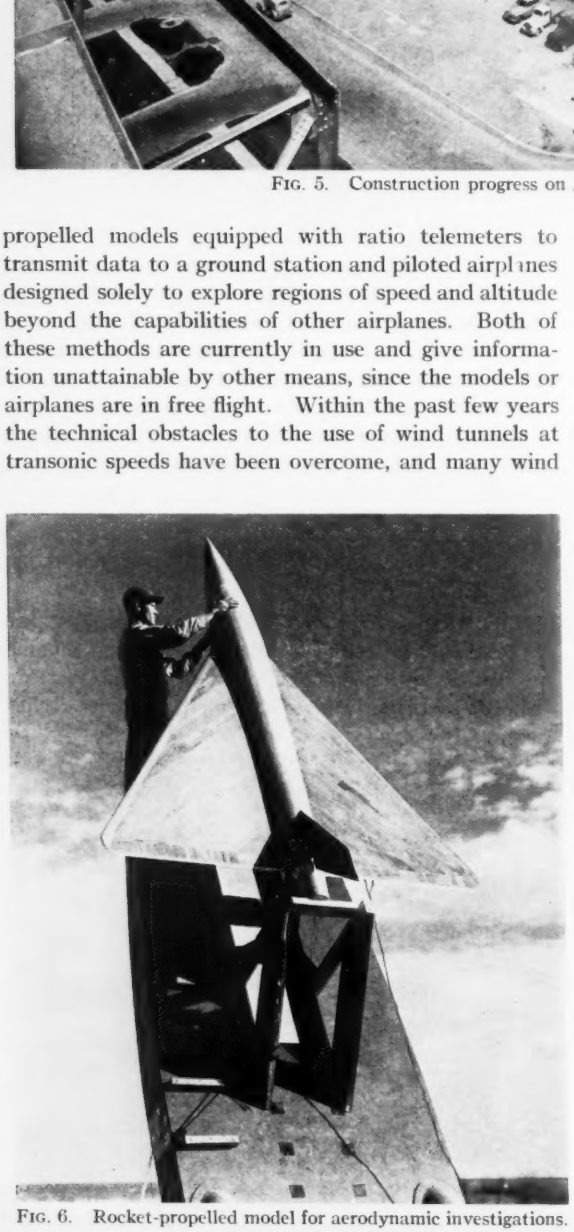


FIG. 6. Rocket-propelled model for aerodynamic investigations.

EXPERIMENTAL RESEARCH GUIDES THEORY

The development of experimental tools permitted the realization of experimental situations of a sufficiently well-defined and simple character to permit direct and detailed comparison with theoretical predictions. Basic research of this character has grown from small beginnings to solid achievement during this first 50 years. The constant interplay of theory and experiment has served to refine both the theory and the experimental techniques. The process has converged to a firmer understanding of the aerodynamics of actual fluids. A few examples must suffice.

A typical early coordinated experimental and theoretical investigation is that of Fuhrmann on airship models carried out at Göttingen in 1912. Pressure distribution was measured on shapes theoretically derived from perfect fluid theory by superposing a source and sink distribution on a parallel flow. The observed discrepancies occur near the tail where the thickened boundary-layer produces departures from the classical potential flow. Later investigations by Munk dealt with the transverse forces on airship hulls at an angle of attack. Comparisons of theoretical and experimental results for two-dimensional struts were given by R. H. Smith and for symmetrical Joukowski airfoils by Fage, Falkner, and Walker. Such comparisons indicated the utility of the classical theory of an incompressible nonviscous fluid in describing the general field of flow and the need for understanding the flow in the boundary layer to account for the drag.

A general acceptance of Prandtl's boundary-layer concept was delayed for 20 years until it became possi-

ble to make measurements of the velocity distribution within the boundary layer itself. The pioneer measurements were made by Burgers and van der Hegge Zijnen at Delft in 1924, and further studies were made by Dryden and his collaborators at the National Bureau of Standards. These fully confirmed the boundary-layer theory and opened up a long trail. As inferred by Prandtl in 1914 from measurements of the drag of spheres by Eiffel and Weiselsberger, the flow in a boundary layer does not remain laminar at large distances from the nose. From the year 1883 when Osborne Reynolds first observed transition from laminar to turbulent flow in a pipe, theoretical workers have labored to develop a satisfactory theory of the instability of laminar flow. Early attempts involved the use of many assumptions to decrease the difficulty of the computational problem. Finally, Tollmien (1929) and Schlichting (1933) presented a theory that seemed satisfactory from the theoretical point of view but which was not in agreement with the experimental data then available. The experiments indicated that transition resulted from external disturbances of finite magnitude, in particular, from the small turbulent fluctuations of the air stream in most wind tunnels and from surface roughness. This discrepancy was finally resolved when, in August, 1940, Schubauer and Skramstad, of the National Bureau of Standards, observed the spontaneous oscillations predicted by the Tollmien-Schlichting theory. This observation was made in a wind tunnel of very low turbulence, a development that rested on extensive measurements of wind-tunnel turbulence by hot-wire anemometers, and of the effect of wire screens in producing and damping turbulence, as well as on extensive theoretical work by G. I. Taylor and Th. von Kármán.

Experimental measurements on airplane wings were made in the earliest wind tunnels, and at an early date families of airfoils were studied in which systematic variations were made in thickness, camber, location of maximum ordinate, aspect ratio, and other geometrical parameters. In the twenties, theoretical families based on the Kutta-Joukowski theory were included and experiments made in such a manner as to approximate two-dimensional flow. The results showed the experimental lift to be smaller than the theoretical, but the pressure distributions for the same lift showed good agreement except near the trailing edge. In later years, methods were devised to take account of boundary-layer effects.

Reference has already been made to the experimental programs for comparison with the Prandtl theory of wings of finite span. This theory has been applied and correlated experiments made on such questions as lift-curve slope, induced drag, downwash field, span-load distribution, control effectiveness, and stability derivatives.

In the supersonic field we find many examples of comparisons of experimental with theoretical results and the resulting interaction of experiment and theory. A typical example is NACA Technical Report 1033 in which Vincenti compares the results of linear supersonic theory with experiment for the minimum drag, lift-curve slope, and aerodynamic center for a family of airfoils of varying aspect ratio, sweep angle, and location of maximum thickness. The results illustrate the importance of viscous and interference effects at supersonic speeds.

Basic aeronautical research today advances most rapidly by this interrelation of theory and experiment which produces rational design procedures whose accuracy and limits of applicability have been established by suitable experiments.

Applied Aerodynamics

The third facet of present-day aerodynamics is applied research devoted to inventions and inventive concepts in order to provide design data. This type of research began in the earliest days of flight and has grown to be a major activity of the NACA and other national aeronautical laboratories. In spite of the years of effort devoted to the development of aerodynamic theories and to experimental exploration of the regions of their validity, we do not have sufficient knowledge to compute the forces on a body of arbitrary shape.

In 1915 in a paper at the International Engineering Congress held in San Francisco, J. C. Hunsaker comments on this problem as follows: "By the use of models, complex problems of aerodynamics as applied to aeronautics may be investigated experimentally without any knowledge of the actual fluid motion present, provided the results are interpreted with full consideration given to the requirements of dimensional homogeneity . . . . Inadequate theory employed as a guide in a qualitative sense, is better than no theory at all; also there is always the possibility that, stimulated by the pressing demands of aeronautics, there may be important contributions to our conception of fluid dynamics, and that eventually what is now but half understood may be made clear . . . . The aeronautical engineer, like the hydraulic engineer, is little concerned with the physical explanation of the force with which he has to do. His stock in trade is the collected data from experience. An important part of his work is the application in the design of aircraft of the aerodynamic coefficients published by the laboratories." Through the years much that was but half understood has been made clear, but the aircraft designer must still rely heavily on aerodynamic coefficients published by the laboratories.

Wing Research

Applied research on wings has been active throughout the history of flight. The design of the wings of the Wright Flyer was based on a systematic series of wind-tunnel measurements, and a major task of the wind tunnels of 1910 to 1920 was the determination of the lift, drag, and pitching moment, of 3- by 18-in. airfoils. This early work led to such sections as the RAF 6 and the Clark Y airfoils which were extensively used in the 1920's.

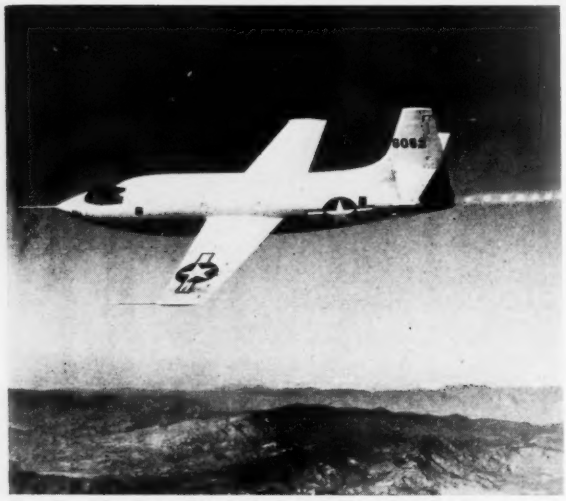


FIG. 7. The first piloted airplane built primarily for research in high-speed flight.

Following the impact of Prandtl's three-dimensional wing theory, and Munk's theory of thin wing sections, extensive study was made of families of airfoils. Between 1929 and 1934 the NACA Langley Laboratory designed and tested more than 100 wing sections. Of these the NACA 23012 airfoil was widely used throughout the world. Its maximum lift was about 8 per cent greater and its minimum drag nearly 20 per cent less than that of the Clark Y airfoil.

One of the landmarks in wing improvement was the development of laminar flow airfoils by E. N. Jacobs and his colleagues in 1938 and 1939. Theory was by now giving some guidance. If the boundary layer flow could be maintained laminar over a greater part of the wing, the drag could be greatly reduced. Prandtl had noted that a falling pressure retarded transition to turbulent flow. The solution then was to design an airfoil in which the pressure continued to decrease for as great a distance as possible without encountering separation in the region of rising pressure near the trailing edge. Theories were developed to permit computation of the airfoil shape to give a specified pressure distribution. Tests of the new airfoils in conventional wind tunnels were disappointing, since the comparatively large turbulence of the wind tunnel air-stream induced premature transition. Not until a low-turbulence wind tunnel was available in 1938 could the striking reduction in drag be demonstrated. The new type of wing was first tried on the North American P-51 Mustang fighter. German wartime reports tell of tests of Mustang wings which demonstrated their superiority to contemporary German wing sections.

As aircraft speeds increased, another advantage of the laminar flow wings was noted. These wings accelerate the air more gradually over the upper surface so that an airplane with such wings can go to somewhat higher speed before the local speed reaches the speed of sound. With special attention to this point, wings were developed which could go 50 m.p.h. faster than conventional wings before encountering the serious effects of compressibility associated with approach to local sonic speeds.

However this was not enough to satisfy the demands of practical development. Jet propulsion came into the picture in the forties. The search began for wings with the drag rise delayed to still higher speeds and reduced in magnitude. This led to much thinner wings, wings of reduced aspect ratio, and wings of sweptback plan form. In 1947, supersonic level flight was accomplished and the problem of developing supersonic wings took on added emphasis. In the fully supersonic region theory again becomes of great assistance in guiding applied research.

SLOTS AND FLAPS

The Wright brothers controlled their airplane laterally by warping the wing structure to reduce the angle of attack on one side and increase it on the other thus decreasing and increasing the lift. This method was soon replaced by ailerons, simple hinged surfaces at the trailing edge of the wings which effectively modified the shape of the wing near the tips. Later Fairey developed wing flaps extending along the whole span of the wing which could be deflected downward to increase the lift for landing, thus reducing the landing speed. Applied research on flaps has engaged the attention of many aeronautical engineers from the 1920's onward.

Another invention of this period was the leading-edge slot invented by Handley-Page in England and Lachmann in Germany. This device was proposed also as a means of increasing lift coefficient, and it was soon combined with the flap for the same purpose or with the ailerons to improve lateral control near the stall. Innumerable variations were proposed and tested including an auxiliary airfoil or slat and linkage such that under the air loads the slot would be closed at low angle of attack and automatically open at high angle of attack. This arrangement is used today on the F-86. Slots have also been used at the leading edge of the flap itself. Thus, whereas a simple flap on an NACA 23012 wing increases the maximum lift by 54 per cent, a slotted flap increases it by nearly 80 per cent. A double slotted flap, in which there are two flaps in series each with a slot, more than doubles the maximum lift.

Many other types of flap have been investigated to give the aircraft designer quantitative information on the effects of the innumerable design variables. The designer may use the high-lift devices to take off with a heavier load at the same speed, to reduce the landing and take-off speed, or to reduce wing area and thus obtain better high-speed characteristics.

DRAG REDUCTION

Since the drag of the airplane determines the power required for flight, drag reduction has been a continuing goal of applied research. The refinement in external shape which is demanded increases with in-

creasing speed. We have already noted the importance of wing shape and thickness, especially at high speeds. In addition, surface smoothness is an important item. While the effects of protruding rivet heads are not serious at speeds below 100 m.p.h. flush rivets are essential at higher speed, and the ideal is a polished smooth surface free from waviness. Applied research has brought important gains here, but the effects are equally striking for other parts of the airplane.

Studies begun in 1927 showed that the drag caused by air-cooled engines as customarily mounted at that time with the cylinders protruding amounted to about one-third of the drag of the airplane body. Townend in England obtained a marked reduction in drag by the use of a narrow deflecter ring to direct the airflow toward the axis of the fuselage or nacelle, but more striking results were obtained by an extensive program of applied research by NACA which led to the NACA cowling. The first results were described by Weick and his associates in 1928, and soon thereafter the cowling was applied to a Curtiss AT-5A airplane with J-5 engine, with a resulting increase in top speed from 157 to 177 m.p.h. Within 3 years the device was in common use, and it is still a characteristic feature of modern transport airplanes using reciprocating engines. The device was further improved by the aircraft industry and later, as speeds increased, much additional research was required to obtain shapes suitable for higher speeds. In this as in other examples of applied research, theoretical analyses of limited scope were developed which greatly aided in understanding and organizing the experimental results, but these analyses had to be supplemented by extensive experimental investigations to meet the needs of the aircraft designer. Since jet engines do not require cowls, no further work is required on cowls, but the new problems of inlets, scoops, ducts, and exits have brought new demands for more and more applied research.

Many other important drag reductions were accomplished through applied research and invention. Measurements of the magnitude of the drag produced by landing gears were an important factor in stimulating the design and adoption of retractable landing gears. Studies of engine location on multiengined airplanes led to the now almost universal arrangement of engine nacelles in the plane of the wing with the front end of the nacelle ahead of the wing.

Stability and Control

The history of applied research on the aerodynamic aspects of stability and control is one of measurement of stability derivatives; of invention of devices such as spoilers, tabs, aerodynamically balanced control surfaces, chord extensions, etc.; and of detailed study and compilation of design data. In many cases, the device seems to have been related to existing theory that has been experimentally confirmed; in others, it seems to have its roots in pure speculation and imagination. It has always been necessary to undertake extensive experimental work that gives the data desired by designers and which occasionally permits a fairly complete understanding of its operation in terms of the underlying fluid motion.

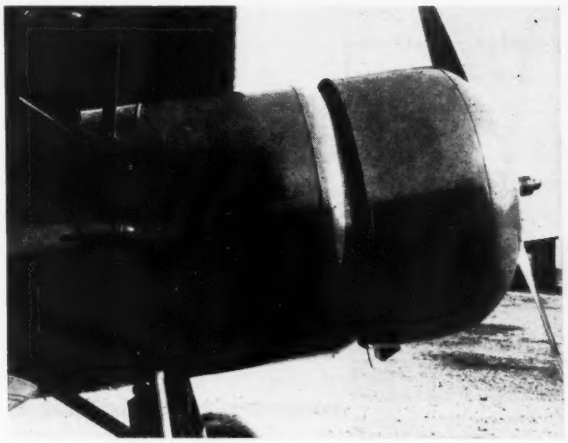


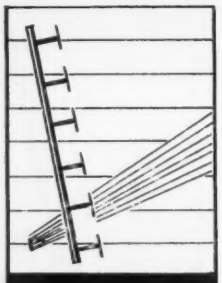
Fig. 8. First application of NACA Cowling to Curtiss AT-5A airplane with J-5 engine, October, 1928.

Air Loads

Within the past 20 years, an almost new field of applied aerodynamics has grown from modest beginnings to a large effort. This is the determination of the air loads to which an airplane is subjected in steady flight at high speed, in maneuvers, and in rough air. Much of this information must be secured in actual flight and some of it, such as gust loads, from statistical records of many hours of flight. The V-G recorder invented by Rhode and Reid in 1930 may be said to mark the beginning of extensive work on gust loads. Necessity for research on maneuver loads was demonstrated by an increasing number of structural failures of military airplanes as speeds increased to 400 and 500 m.p.h. A recent development is the use of wire strain gages for measuring loads in flight.

Concluding Remarks

It has been possible to give only a few typical examples from various time periods in the growth of aerodynamics in the first half-century of flight. Whole areas such as the aerodynamics of propellers, rotary-wing aircraft, cooling, propulsion have had to be omitted. For clarity, theory, experiment, and application have been treated as separate lines of effort. For this there is perhaps some justification, since the aims and habits of thought of workers in applied mathematics, basic experimental research, and applied research are distinguishable. However, the great strength of aerodynamics and aeronautical engineering lies in the close integration and teamwork of the three groups within the last 20 or 25 years. It is this teamwork that augurs well for the future as we face the new horizons of hypersonic speed, low-density aerodynamics in the outer atmosphere, and the imminent problems of aerodynamic heating.



STRUCTURES

Structures—Theory, Materials, Methods

By Hall L. Hibbard

Began as Draftsman, Stearman Aircraft Co., 1928; Advanced to Project Engr. in 3 years. Became Ch. Engr., Stearman-Varney Co., 1931. Joined Lockheed Aircraft Corp. in 1932 as Asst. Ch. Engr. Became V.P. and Ch. Engr. in 1935, and V.P.—Engrg. in 1952, his present position.

AVIATION'S ARRIVAL AT THE first half-century point since man began transporting himself in heavier-than-air flying craft is good reason to pause and study where the aircraft industry stands today in light of progress of the past and prospects for the future.

A review of the gains in speed, power, capacity, and efficiency of modern aircraft is a proper part of the celebration of the golden anniversary of powered flight. It is particularly timely to speculate about further advances in the next 50 years, with utilization of the many techniques, ideas, and working materials now existing.

This 50th year is a good time to take stock, to analyze, and to try to sift fact from fancy for the future.

The aircraft structure is essential to whatever improvements may be developed. Any limitations associated with the structure will be limitations on flight itself. It is appropriate, therefore, to place the structure high on the list of "stock-taking" subjects.

One of the very first structure factors to be considered in pondering past, present, and future trends is weight. As weight goes, so goes the airplane. And weight has been going up. Furthermore, it has been going up faster than useful load.

Fig. 1 shows the structural weights of more than 60 types of British and American aircraft now in service, plotted against design take-off weight on a dual scale that covers fighters and also bombers and transports of both long and short ranges. Structural weight of each includes the complete air frame—wing, body, tail, landing gear, controls, and supporting structure—but excludes power plant, instruments, furnishings, equipment, and "useful" load. The graph, with its tangents representing ratios of structural weight to gross weight, illustrates how the structure is an impressive segment of the total. Structural weight ranges between 0.22 and 0.46 for the 60 types of aircraft studied.

Weight of structure materially affects total weight and performance, as Driggs has shown. One arresting lesson from Driggs is that, in the past 15 years, the ratio of structural weight to gross weight on U.S. Navy fighters has increased from 0.30 to more than 0.40. This change contributes heavily to what is called the "growth factor" or ratio of gross weight to military load. Currently, the ratio is about 12. It threatens to become 20. The same pattern, in differing degree, applies also to bombers, transports, and other types.

When power and fuel and configuration are all fixed, even moderate increases in gross weight have a sharp effect on performance. The severe restrictions of performance resulting from relatively small increases in gross weight become extremely significant, sometimes critical, and are engineers' best object lessons for minimizing structural weight.

High-performance aircraft of today, as well as the more spectacular performers now being designed, demand that air-frame structure must be exactly what is necessary and sufficient to the job. To provide any "cushion" is to impose an unfair penalty on the airplane. A plane so penalized may turn into an economic drogue—a competitive impossibility.

Thus it is the purpose of this article to point up some of the things that are "necessary" for the structure of high-performance aircraft and some of the methods available to make the aircraft "sufficient."

Structural Problems

Actually, the basic problems of aircraft structural design are little different today than 50 years ago. The differences are matters of degree rather than fundamentals. Weight, safety, and cost remain key parameters. They have been joined by others that have been born with improvements in performance.

Elevated Temperatures

Any aircraft must have a structure that is strong, durable, and light in its temperature environment. Until fairly recently, aircraft could be designed virtually *in toto* for nominal "room temperature" conditions.

Exceptions were the structure adjoining the engine exhaust system and those compartments containing provisions for controlling power-plant fires. Then thermal anti-icing came along to put the leading edges of wings and empennages on the list of items demanding that materials be selected with an eye to temperature effects. The problem of temperature was accentuated and expanded somewhat when turbine engines and afterburners came into use.

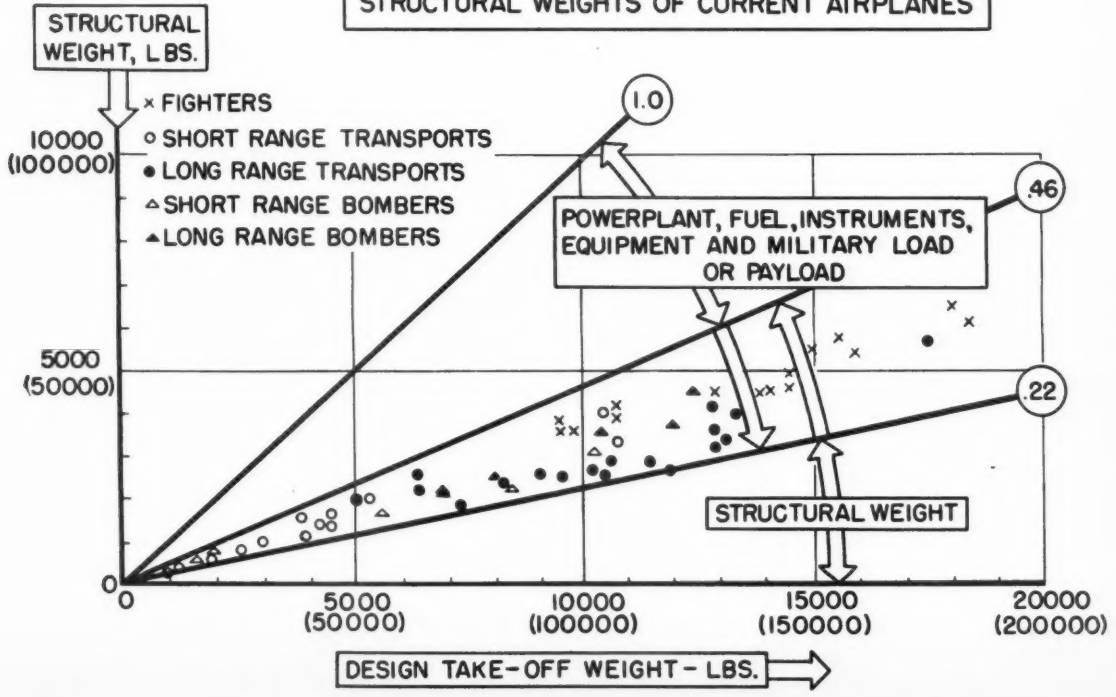
Those problems were relatively easy to solve. Ingenious cooling methods were devised. Materials allowable stresses were reduced a bit, in some cases, and materials with increased resistance to heat came into limited use. Such compromises brought minor weight penalties, but major complications were few.

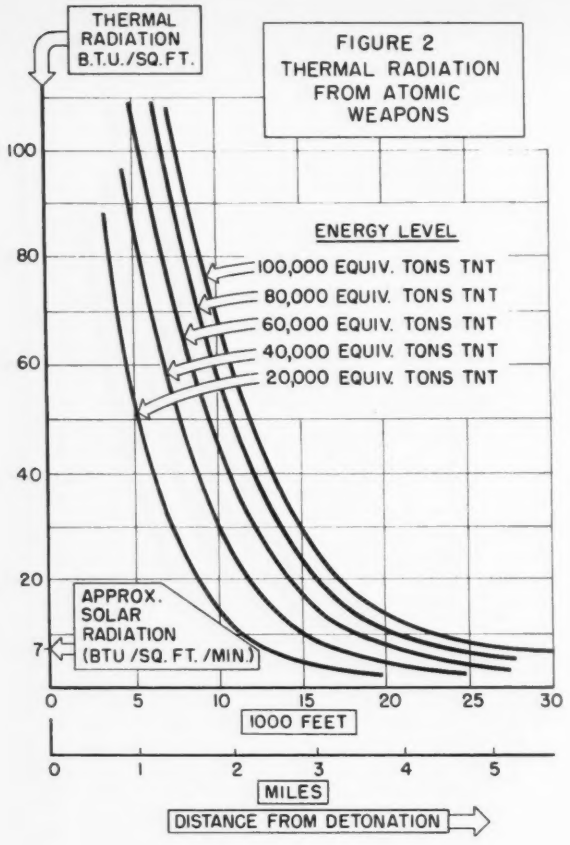
Further advancements beyond the realm of many of the aircraft still flying today have posed far more difficult obstacles, however. At speeds at which airplanes now in design will operate, the entire craft will be submerged in a boundary layer of heated air. The temperature rise of the boundary layer at high altitude can be given approximately as $\Delta T = 75M^2$, where ΔT is the rise in degrees F. and M is the Mach Number. As speeds are pushed upward, the structure becomes bathed in ever warmer air—approximately 1,850°F. at Mach 5.0.

Aerodynamic heating is not the only source of important temperature effects on modern airplanes. It is possible that military aircraft will need to operate in proximity to detonations of atomic weapons. Whether on the air or on the ground, vulnerability of airplanes to such heat-generating weapons must be considered.

The thermal radiation effects from atomic weapons, as shown in Fig. 2, indicate how much heat can be expected at various distances from bombs of various energy levels. Fig. 2 shows that a bomb of the Hiroshima or Nagasaki type delivers about 50 B.t.u. per sq.ft. at all points within about a mile from the detona-

FIGURE 1
STRUCTURAL WEIGHTS OF CURRENT AIRPLANES





tion point in the few seconds during which radiation occurs. This amounts to about seven times the quantity of heat reaching the stratosphere from the sun in 1 min.

Of course, the amount of heat absorbed by a structure depends largely on its material, reflectivity, and angle of incidence to the rays. Yet it is undeniable that aircraft likely to be in the area of atomic detonations must be prepared to undergo exposure to more heat than has ever been forseeable in the past.

The structural designer's principal concern is how heat affects materials and structures. There are numerous corollary temperature problems, too. But some of the most serious effects of heat are—*on the material:* "hot" strength at temperature, "hot" strength after long-time exposure to high temperature, cold strength after various exposures to high temperatures, corrosion protection during and after high temperature exposure, and creep properties (temperature and/or load intermittent); *on the structure:* distortion of aerodynamic contour due to nonuniform heating, strength and stiffness under nonuniform heating, and overall strength and stiffness at high temperature. (It must be acknowledged that these problems have many variants.)

To sum up the temperature situation, it is proper to say that elevated temperatures produce effects of ever increasing importance in aircraft structures. Theoretical methods to predict these effects with accuracy are needed and would be highly beneficial to designers. But, with the practical methods now known, adequate structures are possible.

The considerable quantity of data now available allows the designer, in general, to plan for certain changes in physical properties of metals at high temperatures. He also knows of a number of good materials possessing comparatively high strength-weight efficiency in upper temperature ranges, with minor effects under long exposure.

Nevertheless, a structure expected to operate in conditions appreciably above room temperature must be heavier than for normal environment, assuming that other factors are equal.

Designing for higher temperatures is being aided by an increasing amount of data on creep. As a preliminary approximation, it appears reasonable to design on the assumption that total creep, within the service life of the vehicle, may equal the same 0.1 per cent of 0.2 per cent permanent elongation which defines static-yield strength.

It should be noted, however, that some experiments indicate that "interrupted" creep may ultimately build up to a total exceeding what would develop under continuous exposure for the same duration. More research is necessary on this point.

Nonuniform temperature produces distortion of the aerodynamic contour—a most important effect. Theoretical methods to predict this effect are primitive and laborious. Experimental and mechanical methods to obviate these complications are under development.

New ways to reduce or minimize distortion are turning into well-known principles. Some of these are the close spacing of ribs or webs and concentration of primary material into thick skins.

Also important are the thermal stresses induced by nonuniform heating. Designers need simplified means of accounting for them. Predicting stresses has produced some success, but scaled tests seem to be the best approach at this time. In any event, scaled tests are recommended to verify predictions.

Effects of Nuclear Power Plants

Now that nuclear-powered aircraft are on the drawing boards, a wholly new field of air-frame structural design is opened. At this stage, it appears that structures for fission-engined airplanes will require at least four new air-frame design considerations and at least two new criteria for judging materials.

Some haziness clouds the material picture, but considerable knowledge is already at hand.

Many materials are damaged, mainly in respect to their fatigue characteristics, when exposed to radiation flux. Many become highly radioactive. Considering the many available materials, all encompassing a wide spectrum of elements, the designer will face a major task in recognizing and solving the material selection problem when undertaking a nuclear-powered airplane project.

The four readily apparent effects of nuclear power plants on structural design are points with which most designers have seldom, if ever, been confronted.

First, it will probably be necessary to pursue certain remote-control service and maintenance procedures because of radiation surrounding the power plant. These will dictate some unique accessibilities into the air-frame structure.

Second, the bending relief commonly available in wings that contain large fuel loads will be nonexistent in nuclear-powered aircraft, which will require a negligible amount of fuel. Elimination of fuel stowage considerations should make wing designs simpler and cleaner.

Third, if crew quarters and other sections of the aircraft require fairly heavy shielding as protection from radiation, the dynamic vertical bending response of the fuselage to gusts may become a more severe design requirement than in the past.

Fourth, since there will be an inconsequential difference between take-off and landing weight, landing gear and supporting structure will need to be stronger. No longer will there be the present advantage, in weight-saving, resulting from a landing weight that is lower than take-off weight.

Extensive search will provide adequate answers to these obvious problems and to many others attending nuclear-powered aircraft.

There is no question, however, about atomic-powered airplanes being practical. They are on their way.

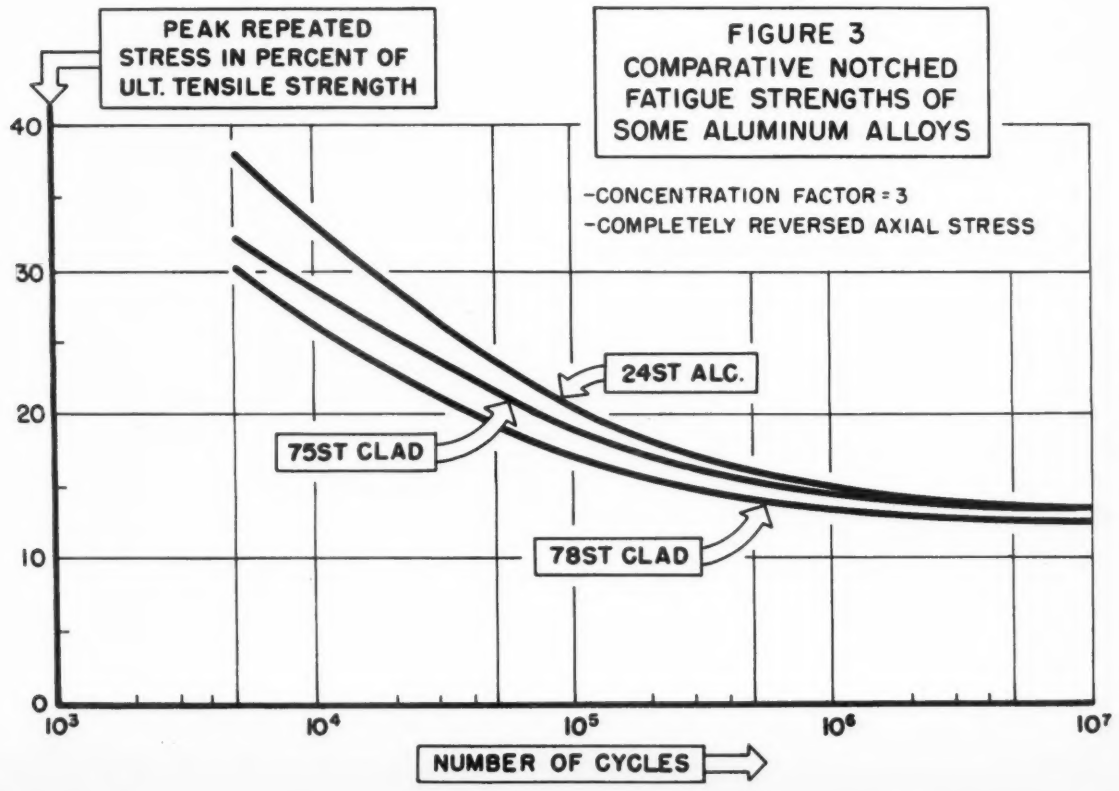
Structural Fatigue

The phenomenon of structural fatigue has assumed growing importance in aircraft design. This can be attributed to a number of reasons. Conservative (or overconservative) design factors are being intelligently thinned out. The utilization of modern airplanes has been rising steadily, both in service and in load. New and stronger materials that are constantly coming along invite the fullest exploitation.

Contributing to fatigue phenomena is the insatiable demand for minimum weight. This goal has cut from the structure much of the excess material once used because of ignorance of the exact magnitude of applied and allowable stresses. As a result, actual stresses have been increased.

New materials and new alloys add to the problem. Possessing steadily increasing static properties, these stronger materials, when used in the usual fashion, bring about a decrease in the amount of metal supporting a given load. Consequently, the actual operating stresses turn higher.

New materials generally do not show the same degree of improvement in fatigue properties as in static physical properties. Illustrating this point, Fig. 3 shows (in per cent of ultimate tensile strength) the fatigue strength for several materials that have a stress concentration factor of three. (A factor of three is hard to achieve in normal air-frame structures. It often may be higher.) Fig. 3 shows that, when designed to the same static strength, higher strength alloys may in



many cases have shorter service lives than so-called "weaker" materials.

Higher tensile properties should not be exploited to the maximum in structures repeatedly loaded in tension. Thus, in some situations, it will be necessary to provide more structural weight than would otherwise be optimum.

Hot-forming and other fabrication methods are being used in an effort to avoid producing appreciable residual tension stresses. Such stresses can result in fatigue difficulties even in members that normally have compressive loadings. Stress analysis, minutely meticulous, is employed almost universally to spot any abnormal stress concentrations. Fatigue testing of whole structures, or sizable parts thereof, subjected to critical flight responsibilities is generally practiced.

Phenomena of fatigue are not subject to accurate prediction by theoretical methods. Many variables weigh on the service life, with the result that statistics on service life deviate over a wide range. Much is being done to enable the designer to provide a high average service life. He has statistical load data, material data, detail design improvements, and laboratory testing facilities. The operator seeking to safeguard the life of the craft is enabled to have reasonable control of the problem by improved inspection methods (such as dye penetrants and portable X-ray) and special maintenance techniques. One fatigue warning device that may prove effective is a pack of coupons with graded stress concentrations in them. When bolted to a structural member, this device can integrate load experiences and environmental conditions of the structure and help forecast trouble in an individual aircraft. Further development is probable.

Structural Rigidity

Higher speeds, thinner wings, stronger materials, and more refined design have caused a change in the concepts that once prevailed on the subject of stiffness. In the past, when an aircraft structure was generally designed to meet a specific strength requirement, the resultant stiffness usually was adequate. Sometimes it was necessary to add some weight for more stiffness, beyond what was inherent, to correct special flutter or resonant vibration problems; but these instances were rare.

It is substantially true that strength considerations dictated the structure weight until the modern plane arrived on the scene.

It is also true that flexibility is not always undesirable, as in the Wright brothers' airplane, where the wings' twisting tendencies were exploited for lateral control. Yet flexibility normally has undesirable effects.

One such effect is reduced aileron effectiveness. Adverse twisting of the wing by the aileron loads results, in extreme cases, in aileron reversal. Aileron effectiveness tends to be lessened with increases in speed and decreases in wing torsional stiffness. This requires two alternative corrections—either the designer must find other means of lateral control, such as spoilers, or he must provide greater torsional stiffness in the structure.

There is another phenomenon resulting from the combination of higher speeds and more flexible structures. It is the divergence that is caused, for example, when the twist on a wing from an airload induces an added twist greater than the first. This kind of structural-aerodynamic instability may necessitate more stiffness, in order to produce a divergence speed well beyond the airplane's attainable speeds.

This method of adding stiffness for minimum weight produces a new structural problem. In designing for maximum stiffness to weight ratio, there can be no reliance on the well-known cardinal principle that, to provide maximum strength for minimum weight, stress should be everywhere a constant and as high as possible.

For example, it develops that, in the case of a linearly varying twist on a tapered tube, the optimum distribution of thickness for the tube may vary. The thickness will be different depending on whether the criterion is strength or stiffness. This is representative of the problem in larger structures where stiffness is a prime consideration.

Since strength is always a requirement, the structural designer's task is to provide both the necessary strength and stiffness—and for the least weight. Structural theory for these problems is adequate, but those methods and principles that in the past have become almost habit can no longer be used promiscuously.

Also worthy of review is the class of phenomena of structural flexibility where the rate of deformation with time is the significant factor. These "transient" or "dynamic" phenomena are generally (although not exclusively) a problem on larger, more flexible aircraft. They are accentuated by thin wings, large overhanging masses such as nacelles and tip weights, and rapidly applied loads.

Whereas it once was adequate to treat maneuvers, gusts, and landing load conditions as "static" cases and to consider the airplane as a rigid body, the designer now must weigh added factors. Frequently it is the case that the rate of application of load and the time response of the structure must be applied. The added factor of time necessitates careful scrutiny of the design condition itself to avoid the overconservatism that would result from simply adding the dynamic effect to the traditional static situation. To obtain a design just "necessary" and "sufficient" for its purpose, it becomes necessary to include the probability of occurrence of the several rates of loading with the probabilities of occurrence of the other variables.

It is possible to predict these dynamic effects reasonably accurately, and experimental methods of verification are usually available.

Dynamic effects will become increasingly significant for large transports and bombers and similar types, it is believed. Small fighters and most missiles generally are not seriously affected, by virtue of their compact

design and rigid construction; but by no means are they completely free of these effects.

Some added weight is foreseen in most instances, either for increased structural stiffness or for damping devices to suppress the dynamic effects.

Structural Methods

Recognizing and facing up to structural problems resulting from aerodynamic phenomena is only part of the problem of designing an airplane in an efficient and practical manner. Men and tools and materials are key ingredients of the overall job.

Man power is the most important part of a successful design. That was just as true 50 years ago as it is today. Effective utilization of man power is more important today, however, than ever before.

In most aircraft manufacturing companies, there has been a trend toward engineering specialization as aircraft performance standards increased and design demands grew more refined. Experience has taught that specialized groups are essential in order to deal with maximum effectiveness with such complex subjects as aerodynamics, flutter, materials, processing and mechanisms—and the structure is no exception.

Most companies now assign groups of specialists to handle stress analysis and to assist in structural design. This work, in turn, is often separated into specialized functions of structural design and stress analysis, basic design loads, dynamics, development, testing, and methods. This type of organization enables a maximum of experience to be focused on whatever special problem arises.

Specialization not only quickens and broadens technical developments but, as specialists groups gain in experience, reduces the work of other groups.

One example of a specialization benefit is in the number of structural design conditions that must be examined. Since the structure must be adequate for all weights, speeds, altitudes, center-of-gravity positions, maneuvers, and pertinent configurations of both external and internal stores within its operating limits, the engineer is confronted with an enormous number of possible and practical combinations of these variables.

Some combinations may produce critical shears, others may cause critical bending, and still others may set up critical torsions.

To avoid noncritical conditions, it is mandatory to have knowledge and understanding of both structural arrangement and loading criteria.

In one Lockheed military cargo airplane, there were 2,400 practical combinations of these conditions for the wing design. But, by using a group specializing in such work, only 17 combinations had to be pursued in the structural design.

Effective organizational refinements have been obtained by establishing specialist groups to perform high-speed computing, to develop analysis methods, to analyze unusual dynamic or structural problems, and to conduct tests.

While specialization is a vital factor in man-power utilization, overspecialization is an ever present danger. Furthermore, specialization makes coordination and scheduling more difficult.

Consequently, at Lockheed and numerous other companies these functional groups have been subdivided into units assigned to one certain model of aircraft. This method incites schedule consciousness and project spirit.

To combat and minimize the evils of overspecialization, Lockheed makes periodic placement changes, provides technical courses in varied subjects, and operates rotational training.

Proper employment of man power quantity-wise, as well as quality-wise, is most important. Experience over many years indicates that there is a definite relationship between the number of stress engineers and the number of designers and draftsmen needed for optimum results in the design development.

Peak employment of structural personnel should come early in the design stage. It is proper practice to have structures personnel reach full strength several months ahead of design personnel. The design groups should reach maximum quantity while functional design is at its peak, after the air-frame structure has been released for the start of manufacturing preparations.

The proper ratio of structures personnel to design personnel during the initial design and layout stage should average about 1:3, peaking at around 1:2 when detail design begins and preliminary design is concluded. It has been found that during this initial stage structures personnel can provide the greatest assistance in securing the best structural arrangement.

The ratio declines rapidly, as a rule, during the detail design phase. It averages about 1:5 and climbs to 1:10 at about the time when release of structural drawings to manufacturing is complete.

From this period to the time of initial flight, stress engineers provide structural assistance in the designing of functional and equipment installations. As they complete stress reports and prepare data for static tests, the ratio of stress men to design personnel averages around 1:12.

Thereafter, the number will depend largely upon production changes but will hold at about 1:20 during production manufacturing.

The early stage concentration of stress engineers is an important development of recent years. It has become fairly typical of American practices. Only a relatively few years ago, this system was not common, for a few reasonably versatile designers augmented by a few stress checkers could handle the problem satisfactorily before demands on the structure became as serious as they are today.

An important new note has been injected as aeronautical progress has eliminated previous ignorance factors and has required eradication of unnecessary weight. Thoroughness of design once made relatively little difference, but now there is no margin for waste or for guesswork. No longer is it adequate to check typical

structural members at random and prove a positive margin of safety. All structural elements must be analyzed today, and excess weight can be tolerated in none.

The use of tapered members, stepped members, built-up designs, and various other practical methods of eliminating superfluous weight necessitate more comprehensive stress analysis. The need to hold manufacturing costs to a minimum means that stress analysis must be employed to cut down on the number of rivets and attachments wherever possible. Many similar developments increased the need for stress analysis.

One measure of the growing importance of stress analysis is the number of finished pages of stress analysis reports. Twenty years ago, a typical model required roughly 500 pages of finished stress analysis. Today a project requires upward of 5,000 pages.

Considering that one final page of analysis represents about 16 man-hours, it is easy to understand how refined design and improved performance have required more thoroughness. Without question, greater thoroughness has in turn sharpened the refinements and the performance.

Computing Techniques

New tools to accelerate stress computations and to make analysis work less of a drudgery are proving a major boon in aircraft designing. Technical methods that once were completely unusable because of the vast quantity of calculations they required are now not only practical but routine, as a result of new mechanical and electrical computers.

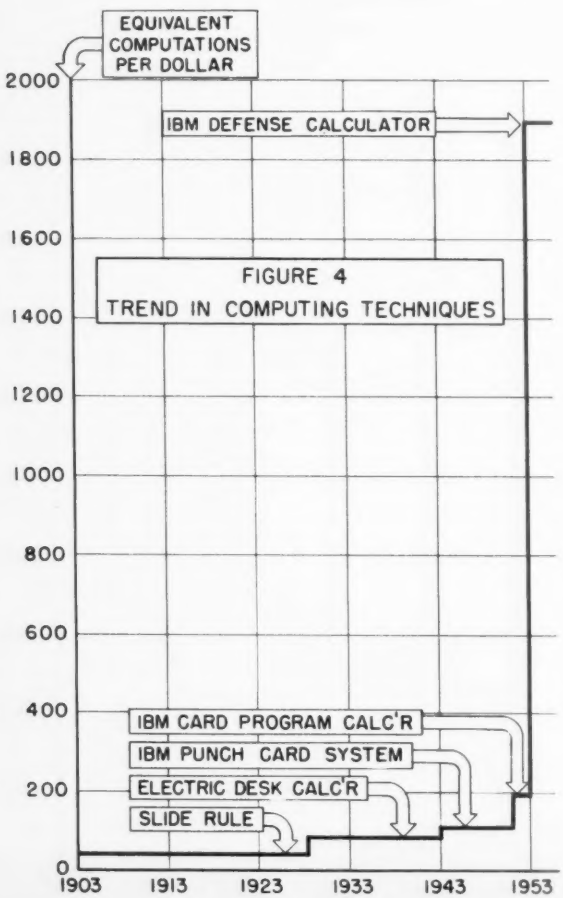


FIGURE 4
TREND IN COMPUTING TECHNIQUES

Fig. 4 shows how several common devices, representing increasing computing capacities, have speeded up design work and opened new technical spheres. The "equivalent operations" in Fig. 4 are based on the use of four significant figures; cost is based on dollars of the day, including checking costs and overhead.

Multiple increases in the number of computations per unit cost not only have facilitated thoroughness in structural work but have also permitted personnel of greatest experience to concentrate on engineering problems.

New computing machines capable of far more service than any now in use are being developed. They will bring about the solution of problems still untried.

With electric analog machines, engineers have already simulated, either mathematically or physically, important static and dynamic structural problems. These techniques are making important strides toward eliminating cut-and-try methods of design. They are making possible unique and optimum structural solutions. Before long, it appears, it may be possible to "machine-design" quickly a complete structure that is just necessary and sufficient for its mission.

Flight-Test Measurements

Scientific measurement of various structural loads under actual flight conditions is growing into one of the most valuable functions of aircraft development. The ability to record with precision the structural loads in flight, and particularly upon landing, is removing much of the guesswork from air-frame design. With precision strain gages and sensitive pressure cells, engineers are determining effects impossible or impractical to measure in the wind tunnel. Examples include transient loads, structural deformations, rapid control motions, and many others.

This technique offers a twofold advantage. Not only do flight-test measurements check the magnitude and distribution of estimated loads, thus decimating a major source of inaccuracy, but they also provide valuable data for future designs.

Wing bending moments have been measured on 19 Lockheed airplanes by means of calibrated strain gages providing accurate and reproducible values. In like manner, horizontal and vertical tail loads, landing-gear loads, nacelle loads, and other significant variables have been pinned down.

Utilizing High Velocity Aircraft Rockets (HVAR), a useful technique for measuring flight loads at high speeds has been developed at Lockheed. The technique involves mounting a small-scale structure on the motor section of a HVAR rocket, firing it, and observing the behavior via camera film recovered after the rocket's flight. Tests have been made with a large number of

model wings with scaled strength and stiffness and with a variety of configurations. Recently, the technique has been extended to include quantitative data by means of telemetering.

No longer is the wind tunnel the sole source of structural load design data.

The inevitable result of continued development and exploitation of flight-test techniques will be safer, lighter, and more realistically designed structures.

Structural Test Methods

One of the fastest developing aspects of aircraft designing and manufacturing has been the progress in laboratory research and scientific testing. Fifty years or so ago, testing devices consisted principally of a spring scale and a few sandbags. The array of machines and scientific equipment on hand today in aircraft laboratories is probably second in engineering usefulness to those of no other commercial industry.

To mention only a few, Lockheed uses fatigue testing machines, landing-gear drop-test devices, impact machines, universal testers, spectroscopic equipment, environmental test chambers, and extensive electronic instrumentation.

To determine stress distribution in intricate structures, many types of strain gages are used. Brittle lacquer is also employed to erase guesswork. The fine-wire failure detector has helped determine the origin and sequence of failures in structural tests.

The laboratory facilities supporting today's designer would cause yesterday's designer to blink in astonishment. Modern laboratories are contributing increasingly accurate observations of structural phenomena and more data to support advanced design.

Comparatively few years ago, it would have been all but impossible to test the type of large and highly loaded aircraft now in being. With elaborate testing tools at his command, today's designer can pursue more progressive steps with greater confidence and in an atmosphere of economy and accuracy. Some of his avenues to progress are continuous development of hydraulic loading systems, universal fixtures, load maintainers, cemented tension loading patches, and automatic recording systems. They all are steps to increase safety and improved service for heavier-than-air craft.

One noteworthy field of testing brought into prominence by design advancement concerns highly pressurized aircraft for high-altitude flight. The huge volume of compressed air required to test pressurized cabins on the ground constitutes a major explosion hazard. Possibility of a failure under pressurization is even more dangerous in ground testing than in flight. Various test techniques are practiced.

The practice in England appears to favor submerging the cabin in a large tank of water and applying pressure inside. Apparently such tests have not been adopted in the United States.

Lockheed has successfully utilized a method that employs large paperboard cylinders interspersed with cast foam-plastic "bricks." The cylinders have small holes that bleed air slowly. The general purpose is to fill most of the cabin space with cylinders and bricks, leaving only a fraction of the cabin volume to be filled with compressed air. This method, light and inexpensive, has proved to be quite successful.

Stress Analysis Aids

A rising volume of technical literature in the field of stress analysis is furnishing a vast reservoir of useful analytical methods. All around the world, research institutions are recognizing that there is a need for a proper balance between aerodynamic and structural information. Useful reports on stress analysis, material properties, and applied loads are being published in gratifying volume.

So great are the quantities of this information that indexing and machine-sorting methods are being developed to increase the utility of the data and make them readily available to the engineer.

Most companies' engineering departments now contain structures manuals, which condense the more generally useful methods and data, permit consistent methods, and reduce the chance of error in analytical work.

A large quantity of useful data is available in Government handbooks, such as *ANC-5*, "Strength of Aircraft Elements."

Despite rapid progress in testing, solutions are lacking for numerous problems. Two examples are: (1) the need for a practical method of simulating temperature effects in large structural tests, and (2) the need for a direct means of separating thermal strains from air-load strains in diving flight tests.

It is self-evident that, with the powerful methods and devices at hand for attacking aircraft structural problems, the industry can expect to provide structures that are fully practical and safe for the high performance aircraft of tomorrow.

Structural Materials

Although studies of aerodynamic effects and manpower utilization and testing procedures are all instrumental in tailoring better aircraft, these subjects are no more important than the material that goes into the structure.

Early in the age of powered flight, the man who designed an airplane was compelled to accept and use "borrowed" materials. He had to "make do" with things that were created with no intent of application under the severities of flight. All of that has been changed, fortunately, and much of the progress in aircraft design can be attributed to the specialized attention of material suppliers to the novel needs of the aircraft maker.

Fig. 5 furnishes a graphic picture of the steady increase in specific strengths (ultimate strength divided by density) of principal aircraft structural materials used in the past 50 years. Wood of many kinds was

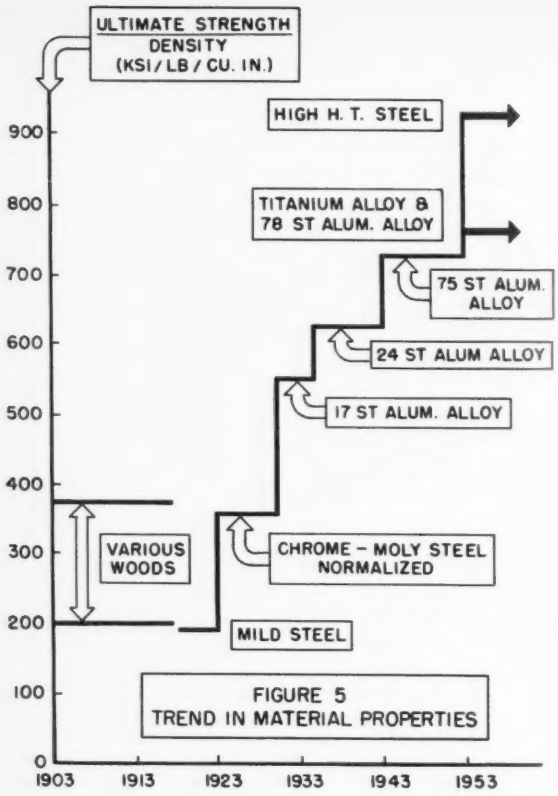


FIGURE 5
TREND IN MATERIAL PROPERTIES

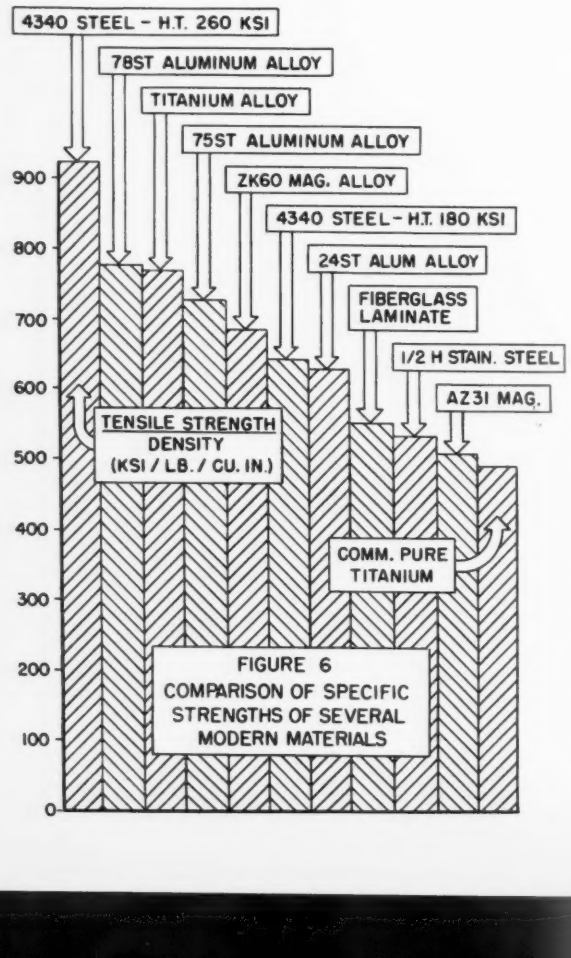


FIGURE 6
COMPARISON OF SPECIFIC STRENGTHS OF SEVERAL MODERN MATERIALS

the early choice, and logically so. Wood was the optimum material for air-frame construction over much of the early period of flying, and it has been applied in numerous airplanes since because it compares favorably on a strength-weight basis with some modern metals.

Considerations of sheer volume rule out wood for modern high-performance aircraft. Wood had to yield to the inviolable law that the airplane must be as large as possible inside and as small as possible outside.

The fundamental demand for the structure to occupy as small a space as possible and for its elements to be deployed efficiently is once again bringing about an important change in construction methods and materials, particularly as wings become thinner and loads greater

Although today's aircraft is composed of a variety of materials, aluminum alloy remains the predominant material in both structural and nonstructural applications.

It is informative to review the distribution of weight in a current American fighter, both as to per cent of gross weight and empty weight. Aluminum alloy totals 55 per cent of the weight empty—counting 22 per cent in nonstructural applications and 33 per cent in structural applications.

For that structure which is defined as material having the main purpose of supporting flight or ground loads, aluminum alloy amounts to about 75 per cent.

A similar distribution in terms of weight empty is found for transports and bombers.

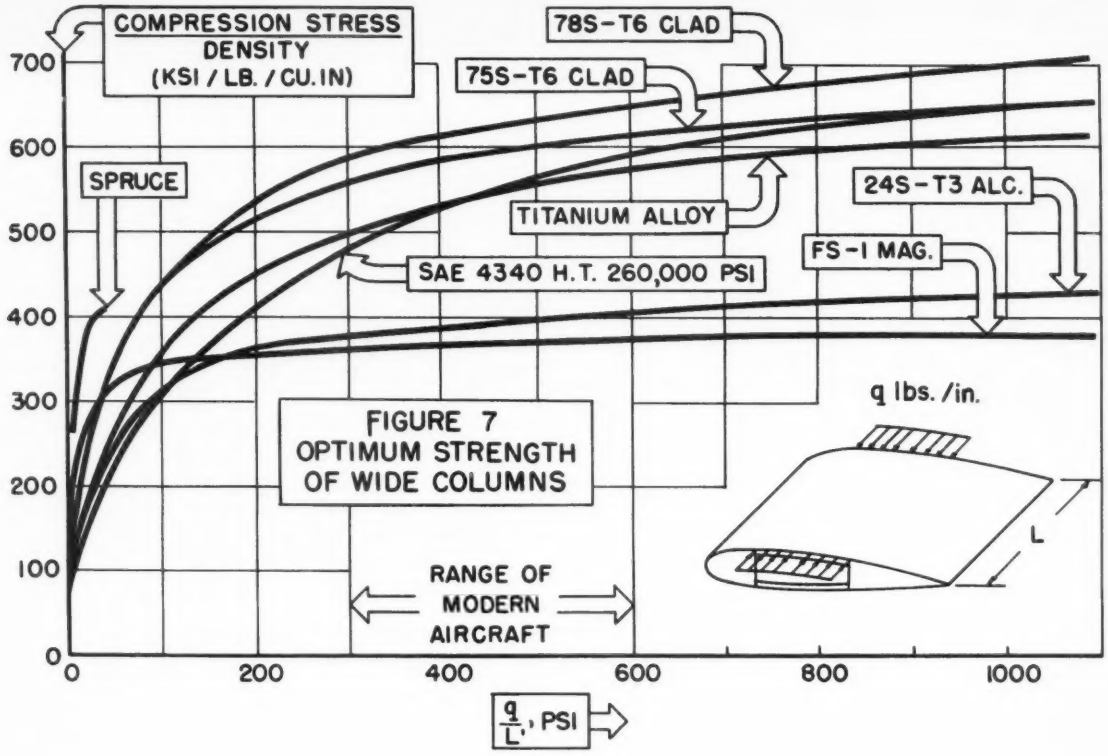
Nevertheless, a significant amount of the structure is composed of other materials, whether in production or prototype models, and these materials should not be ignored.

Fig. 6 presents, in bar-chart form, the specific tensile strengths of principal structural materials available for aircraft structures. Although many other tempers and forms are obtainable, those shown in Fig. 6 are sufficient to illustrate the impressive variety of highly efficient materials available. Some have been in use a long while, whereas others are relatively new. Comparison of new materials with the older and more familiar materials is illuminating.

78ST Aluminum Alloy

A recent newcomer is the aluminum alloy designated 78ST. Properties of 78ST represent another forward step in the progressive improvement of aluminum alloys. Comparison of its properties with 24ST and 75ST shows that the tensile and compressive properties of 78ST are 6 to 10 per cent higher than for 75ST, which in its turn was considerably stronger than its predecessor, 24ST.

Considering the ascending problems of fatigue, it is reasonable to deduce that the tensile properties of 78ST will rarely be exploited and that its greatest con-



tribution to aircraft structural improvement will be its compressive properties.

Because a considerable portion of the aircraft structure is determined by axial compression forces, it is worth while to show in a general way how 78ST compares with some other possible material choices for compression structures. Bulk, shape, and loading-intensity factors must be considered for proper evaluation of this quality. Fig. 7 shows the optimum strengths for a "wide column," which may be considered representative of structures such as the upper surface of a wing box beam, using the method described by Shanley.

Fig. 7 shows the maximum compression stress, F_{CR}, divided by the density plotted against the loading and dimensional parameter, q/L', where q is the axial loading per inch width applied to the column and L' is the pin-ended column length. At F_{CR} the local crippling and column failure stresses are equal and were derived here for an idealized column composed of a row of round tubes, and thus they are fairly representative of the optimum stresses than can be achieved with these materials.

The approximate magnitude of the load-dimensional parameter q/L', for certain typical structures has been indicated on this figure, and the advantage of 78ST in this régime becomes clear.

Thin, high aspect ratio wings result in more intense loadings and more compact structures. Therefore, the advantage of the strong aluminum alloys declines. On this basis, other materials such as titanium and steel become competitive.

Integrally Stiffened Structure

While not wholly a material development, the advent of integrally stiffened structures merits consideration in any study of materials. Integrally stiffened structures are an answer to the need for simplified structures of low weight and high strength. Higher loads and more compact structures presage a wider utilization of this relatively new technique.

Fig. 8 illustrates an integrally stiffened structure, an inner wing box beam lower surface for the Super Constellation. The complete structure is composed of three pieces 38 ft. long, machined from 75ST plate. The plates are contoured by shot-peening, which, besides contouring, provides a residual compression stress on both surfaces.

Compared with equivalent structures fabricated by previous methods, the integrally stiffened structure in Fig. 8 produces huge volumes of chips, amounting to about 90 per cent of the raw material. Chips are salvaged, however, and resold to the supplier.

Important structural advantages from this technique include improved fatigue properties, reduced shear lag, and simplified sealing. Promise of still more economical production of this type structures is seen in new fabricating methods such as roll-forming and progressive forging.

The value of integral stiffening could be demonstrated by many other examples, but it is sufficient to summarize that this type of construction, utilizing heavy aluminum plate and massive extrusions, is a great new method for building the kind of structures needed for high-performance aircraft.

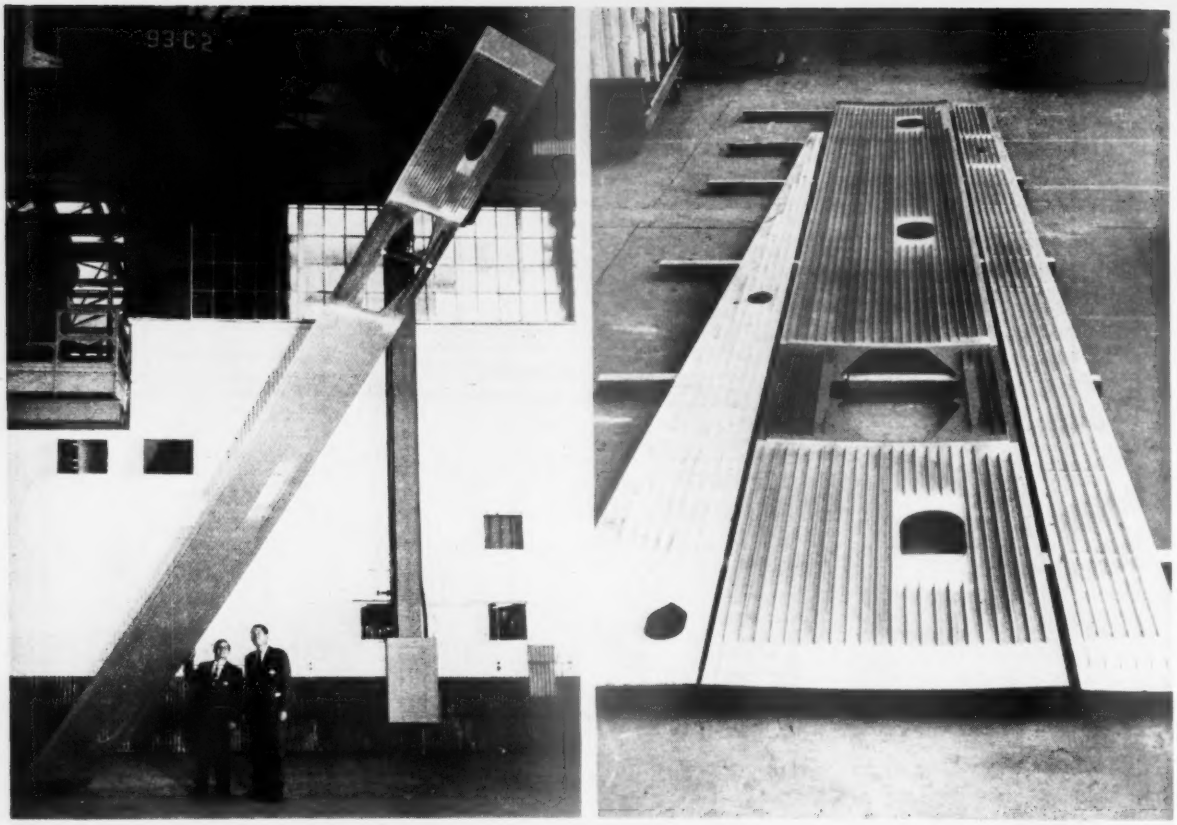
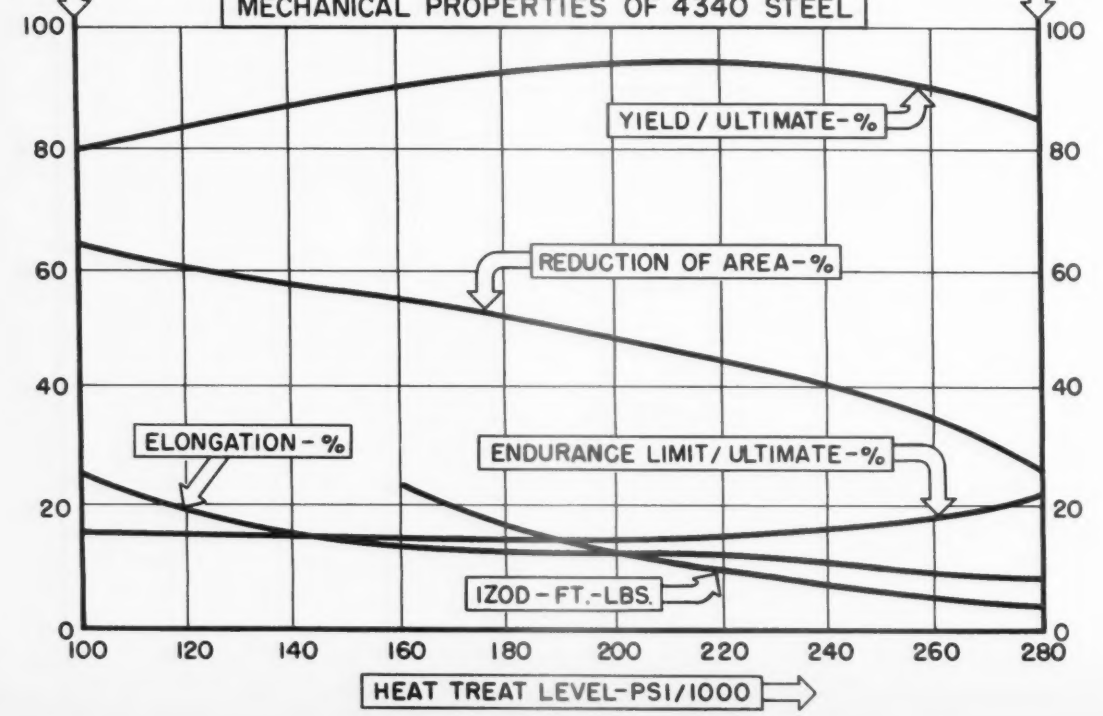


FIGURE 8
MACHINED INTEGRALLY STIFFENED INNER WING
LOWER SURFACE FOR SUPER CONSTELLATION



High Heat-Treat Steel

Steels used in aircraft have, until recently, been generally limited in tempers to the common value of around 180,000 lbs. per sq.in. for fear of reduced ductility, impact resistance, and fatigue life, as well as increased fabrication difficulties. The behavior of other steels, notably tool steel, repeatedly justified this concern. But Lockheed undertook experiments in 1949 to use SAE 4340 steel at the highest level at which it could consistently be tempered, 260,000 to 280,000 lbs. per sq.in. The results have been quite satisfactory.

The Lockheed experiments have indicated that there is some reduction in ductility and impact as compared with previously used tempers. But the reduction is by no means critical. It evolves that there is a larger spread between yield and ultimate tensile strengths, a feature helpful in stress redistribution. This feature is shown in Fig. 9 for SAE 4340 over a wide range of tempers.

Fig. 9 discloses that the notched endurance limit in percentage of ultimate tensile strength is superior at the high heat-treat level to that in the 180,000 lb. per sq.in. range. This effect means that the 180,000 lb. per sq.in. temper, even when fully exploited in static tension, will give a service life at least as good as structures similarly designed at the lower heat-treat level and subjected to the same loading experiences.

Actual operations have shown that drilling, turning, tapping, and cutting, although somewhat more difficult, are practical. The same feeds and speeds may be used as heretofore.

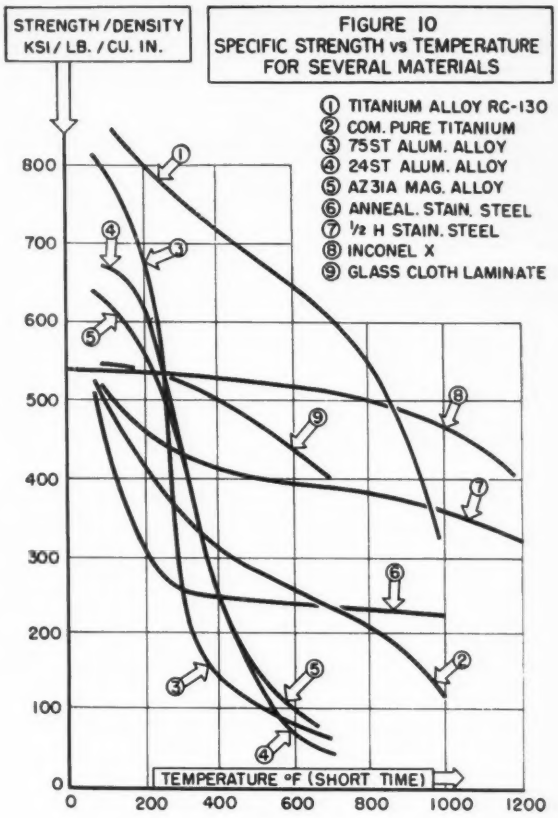
Some processing changes are required but not to any unreasonable degree. Baking must be performed after plating and pickling to eliminate hydrogen embrittlement. Assembly stresses must be avoided.

This material shows promise of affording substantial gains in bending and tension applications. Applications in compression structures are likely to prove efficient as loading intensities increase and structural space decreases.

Titanium

In the face of complications arising from the subjecting of aircraft to higher temperatures, much attention is being given to titanium as a metal that will contribute much to solving heat problems. Importance of titanium development becomes exceedingly important when it is realized that high-temperature problems loom as the biggest foreseeable obstacle to flight at markedly higher speeds.

Titanium promises to play a vital role because of its high strength-weight efficiency at elevated temperatures. Titanium is the ninth most common element and the fourth most common metal in the earth's crust. It has a strength comparable to medium steels. Its density is intermediate between aluminum and steel (0.16 lb. per cu.in.). In both pure and alloyed forms, it is becoming available in modest quantities.



Alloyed titanium has produced some attractive materials, such as Rem-Cru RC-130A. Fig. 10 shows how this alloy compares with several other materials in terms of specific strength vs. temperature (tensile strength divided by density) up to 1,000°F. Fig. 10 indicates that, by this simple criterion, titanium alloy is the most efficient structural material for a wide range of temperatures, and, at moderately high temperatures, its strength-weight ratio compares favorably with that of more common materials at room temperature.

There can be no doubt that titanium is an important contribution to the storehouse of fine materials for future aircraft.

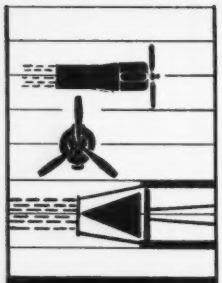
Plastics

Plastics is proving to be a field of particular progress in aircraft construction. Plastic developments are abundant and diversified.

Much of the work in plastics has revolved around canopies and windows, radar housings, and flush antennas, which require materials that, first, are transparent to light, radio, and radar waves of varied frequencies and, second, must have adequate strength and durability to sustain high structural loads.

Canopies with a high critical temperature have been successfully formed and laminated with noncrazing, thermosetting plastic. Laminated thermoplastic canopies have also been produced.

(Continued on page 131)



PROPULSIVE SYSTEMS

A Slipstream View of Aircraft Propulsion, 1903–1953

By Frank W. Caldwell

Foreman, Propeller Dept., Curtiss Aeroplane Co., 1916. Chief, Propeller Br., Engineering Div., Army Air Corps, 1917–1928. Chief Engineer, Standard Steel Propeller Co. and Hamilton Standard Propeller Div., 1929–1936. Engrg. Mgr., 1936–1940; Director of Research, United Aircraft Corp., since 1940.

THE HISTORY OF AIRCRAFT PROPULSION up to the advent of the jet engine is not one of an art basically peculiar to the air as far as the fundamental principles are concerned. The engine, the propeller, and the fuel all had their counterparts in other fields. The uniqueness of aircraft propulsion lay in the intensive and meticulous refinement of all of the components. This effort was carried out on a scale never before approached in any field of endeavor.

Although we are considering the period from 1903 to 1953, it should be borne in mind that the theory of propulsion had been developed to a considerable extent even as applied to air for some time before the first flight was made.

One of the most basic concepts of propulsion is the momentum theory proposed by Froude and by Rankine. In this conception it is recognized that in order to create thrust for propulsion it is necessary to impart a component of velocity to the air or other fluid in a direction opposite to that of the motion. The amount of the thrust so generated is equal to the mass of the fluid per unit of time multiplied by the velocity that is imparted to it—that is, $T = Mv$. The kinetic energy in this air stream is not recovered, and, consequently, it represents a basic loss of energy—in this case the energy loss equals $Mv^2/2$, where v is the velocity of the slipstream with respect to still air.

The useful work is equal to the thrust times the velocity of the aircraft: MvV, where V is the velocity of the airplane.

If we divided the useful work by the total work, we have

$$MvV/[MvV + (Mv^2/2)]$$

and this may be reduced to the form

$$1/[1 + (v/2V)]$$

This conception of the basic limit of efficiency was well understood in 1903 and has remained an important factor in the theory of propulsion ever since. In fact, it has come into considerable prominence with the advent of the jet engines, since this factor of efficiency represents one of the major limitations on the jet machines that operate with a relatively small mass of air at an extremely high slipstream velocity leading to a low value of

$$1/[1 + (v/2V)]$$

The principles of the gas turbine were already under intensive study, though the first operating machine of which I have been able to find a record was built some 2 years after the first flight. This machine was destined to reach its first major importance in the 40th year

of flight and then, first, as a power plant for the airplane.

Before the advent of flight, Froude and Drzewiecki had advanced the concept of dividing the propeller blade into a series of small annular sections and treating each small annulus as an airplane wing flying in a helical path. Drzewiecki, in particular, calculated the effects of the lift and drag of each section and obtained its contribution to thrust and torque so that it was possible by this means to calculate the torque and thrust of the whole propeller—hence, its power absorbed and power delivered and, consequently, its efficiency.

This concept has remained useful throughout the years and is today still a useful tool for the calculation of propellers and of the compressors for the turbine types of engines. Indeed the whole procedure of calculating compressors from basic cascade data is a logical outgrowth of the Drzewiecki concept.

On the power-producing or engine side of the picture, we have to go back a good many years to Carnot's cycle efficiency based on absolute temperatures, where the limiting efficiency is taken as $(T_1 - T_2)/T_1$, where $T_1 - T_2$ is the temperature drop during the work process and T_1 is the absolute temperature at which the fuel is burned. This furnished the background for developing engines of high compression ratio or, more properly, expansion ratio and applies equally to piston engines and other types.

While this basic conception has remained valid over the years, it has perhaps come into more prominence as a standard of reference during the last few years when a great variety of power cycles are being studied and analyzed. While it remained in the background during the piston era, so many practical concepts were involved that it was perhaps of less importance as an everyday matter of reference.

In fact. many of the concepts of aerodynamics and thermodynamics which remain valid today were available at the beginning of the century.

The basic four-stroke cycle for the internal combustion engine had already been worked out for the automobile and for other uses. The major problem then was the development of an engine sufficiently light in weight to be suitable for flight use.

One cannot help but be impressed by the sound approach of the Wright brothers to the problem of propulsion. They independently worked out the conception of treating the propeller as a series of annular strips of airfoil section and made tests in their wind tunnel on air foils from which they calculated the performance of the propeller. They understood the importance of the proper relationship between the rotational tip speed of the propeller and the forward speed of the aircraft, and this led them to the development of a drive from the engine which would allow the propellers to turn at a relatively slow speed so as to set up the most favorable conditions for efficiency.

While this posed a rather difficult mechanical engineering problem in the design of a chain drive, the complications paid off in terms of propeller efficiency.

The Wright engine, while adequate, did not represent an outstanding forward step in detail aircraft engine design. The engine was a four-cycle horizontal type with a 4-in. bore and 4-in. stroke, turning at 1,200 r.p.m. The engine weighed 170 lbs. It would deliver 16 hp. the first 15 sec. and then 12 hp. There was no carburetor, and the fuel feed was carried out by gravity injection. The two oppositely rotating pusher propellers were driven through a chain and sprocket drive at 417 r.p.m. The propellers were 8 ft. 6 in. in diameter, and their efficiency has often been quoted as 66 per cent, although this figure may well have been nearer 75 per cent.

From any point of view, it is all the more credit to the Wright brothers, who were not primarily engine specialists, that they were able to carry out a successful flight without the benefit of a more advanced engine design.

In considering the status of engine design in 1903, we have often overlooked the remarkable engine developed by Charles M. Manly for the Langley "Aerodromes." This was a five-cylinder, liquid-cooled radial engine with a bore of 5 in. and a stroke of $5^1/_2$ in. This engine successfully passed a 10-hour endurance test at 52.4 hp. and 950 r.p.m. The engine, complete with feuling system, weighed 187.47 lbs. Manly is given credit for originating the master connecting rod and the high tension distributor, both advanced conceptions for that early date.

In many respects the period from 1903 to the outbreak of the first World War in 1914 was one of the most interesting in the history of aircraft engine design. The geometry of the engine was explored in great variety, and there were probably more than 100 new designs brought out in this period. The Vee-type engine was built in both the air-cooled and liquid-cooled versions, with the number of cylinders varying from two to twelve. Similarly, the horizontally opposed type was built in sizes from two cylinders to eight; the W-type, with from three to twelve cylinders; and the radial type with from three to ten cylinders. They were all built in air-cooled and liquid-cooled versions.

Besides the engines with stationary cylinders, the air-cooled rotary engine was developed to a great extent in France and, by the time of the outbreak of the War in 1914, was the leading contender in that country.

In Germany, the six-cylinder in-line liquid-cooled engine had come to the fore, particularly as exemplified by the "Mercedes." In general, the liquid-cooled engines had reached the weight of a little over 4 lbs. per hp. At this time France was leading with by far the greatest number of designs, having contributed some 22 of the 50 most prominent engines brought out during this period.

In general, the propeller designs were confined to wooden types, and the familiar laminated construction first introduced in Germany became more or less standard and continued so during the life of the wooden propeller industry.

A certain amount of experimenting was done with various kinds of metal propellers and with controllable pitch propellers, but none of these reached a stage of successful flight use.

Most of the engine designing during this period was carried out as an application of the ingenuity of the designers with the objective of better weight per horsepower and improved reliability. There was so little flying, however, that the amount of work done in response to requirements brought out by flight experience was rather limited.

This whole situation changed radically at the beginning of the War in 1914, where actual operations began to point up the real power-plant needs of the flying service.

One of the first lessons learned from the flying experiences in World War I was that the airplane engine differed from other types of power plants in that it was required to operate in varying conditions of air density and suffered a rapid loss of power as the airplane went to altitude. Since altitude performance was of prime importance in military operations for many tactical reasons, the attention of the designers was focused on improving the power output of the engine under the altitude conditions.

In general, three different approaches were taken to the solution of the altitude problem. One was the so-called "overdimensioned" engine, which was built with a great enough displacement to generate the necessary power at altitude but was of too light a construction to operate at full throttle at sea level. This type of engine had to be throttled at low altitude and, in some cases, had to be provided with a compression release device to prevent damage in starting.

In general the Germans followed this practice to a considerable extent, examples being the Zepplin Maybach of 180 hp., the Mercedes of 160–180 hp., and the BMW engine of about the same rating. All these engines were six-cylinder, in-line, vertical, and water-cooled. In most cases, the r.p.m. was kept low—about 1,400, making it possible to obtain fairly good propeller efficiency without the use of reduction gearing.

The second approach to the altitude problem was to design an engine with an extremely high compression ratio and depend on throttling to prevent damage at low altitude.

The third approach was to provide an external device for compressing the air before it entered the engine, and this practice became known from the start as "supercharging."

While supercharged engines did not play a very important part in actual flight operations, during the first World War considerable progress was made on an experimental basis, particularly by Rateau in France and by Moss and Sherbondy in the United States. These experimenters made use of the energy in the exhaust gas from the engine to drive a turbine that, in turn, operated a centrifugal compressor furnishing compressed air to the engine cylinders. This practice became known as "turbosupercharging." Because of the soundness of Dr. Moss's development and the support of the General Electric Company and the U.S. Army Air Corps, this type of supercharger continued in development over a long term, although it was not until the second World War that it reached a major application in practical use.

Another development in propulsion which was given considerable emphasis by the first World War was the controllable-pitch propeller. This device was first thought of as a means of giving the propeller airfoils a suitable angle of attack throughout the range of flight speed so that they could operate with a high L/D and, consequently, with a good propeller efficiency. It was soon realized, however, when a little experimental use of this device was obtained, that it was equally important as a means of controlling the r.p.m. of the engine under varying flight speeds so that the power output of the engine could be maintained from take-off to maximum speed. Generally speaking, for the airplane speed and engine's current at that time, a fixed-pitch propeller fitted so that the engine turned at its rated r.p.m. at the maximum speed of the airplane would hold the engine down to about 85 per cent of its speed at the beginning of take-off. Thus, an improvement of about 15 per cent in engine power could be had by the use of the controllable-pitch propeller while, at the same time, making a small gain in propeller efficiency.

If the turbosupercharger could be developed to the point where the maximum power of the engine would be available all the way from sea level to 20,000 ft., a fixed-pitch propeller fitted for the high altitude would allow the engine to turn at only about 60 per cent of its rated r.p.m. at take-off so that a prohibitive penalty in the way of loss of engine power would be incurred.

The controllable-pitch propeller was thus thought of as a complement to the turbosupercharged engines. Fortunately, an experimental program for the development of the controllable-pitch propeller was initiated at McCook Field during the first World War, and this program was continued on a modest scale for a number of years thereafter.

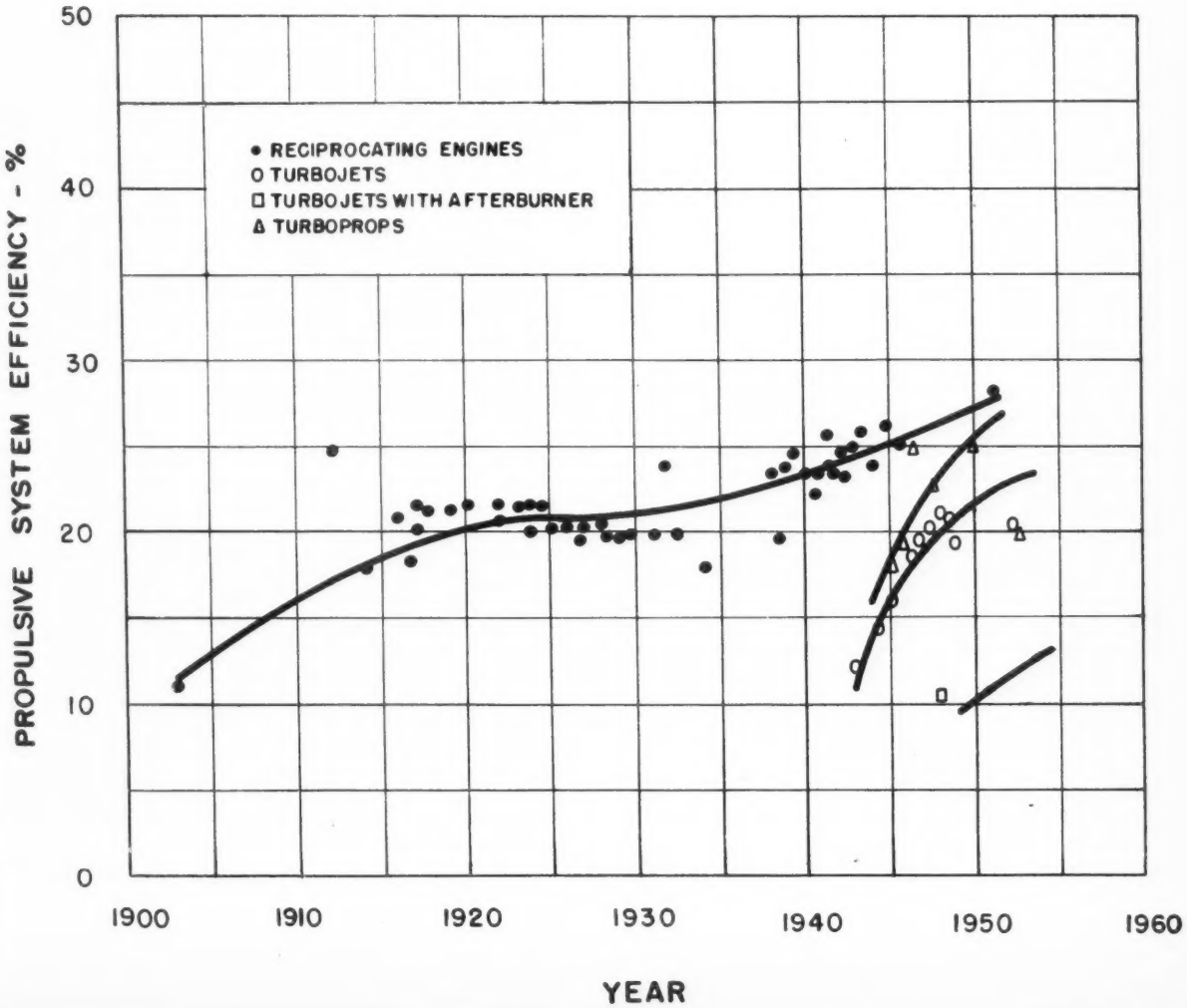
However, the speed of the World War I airplanes was not sufficient to make the controllable-pitch propeller mandatory, and the complication was hardly warranted at that time. Actually, the demand during the War was more directed toward the reversible-pitch propeller, since the use of wheel brakes for landing had not been developed and some sort of braking device was badly needed.

While some airplanes were fitted with reversing propellers, the wheel brakes were soon perfected, and the urgent need for this device was largely removed for some time to come.

While the engine developments of World War I were certainly crude by today's standards, nevertheless a good deal of progress was made, and the end of the War saw the weight of liquid-cooled engines come down to a little over 2 lbs. per hp. and that of air-cooled engines slightly lower.

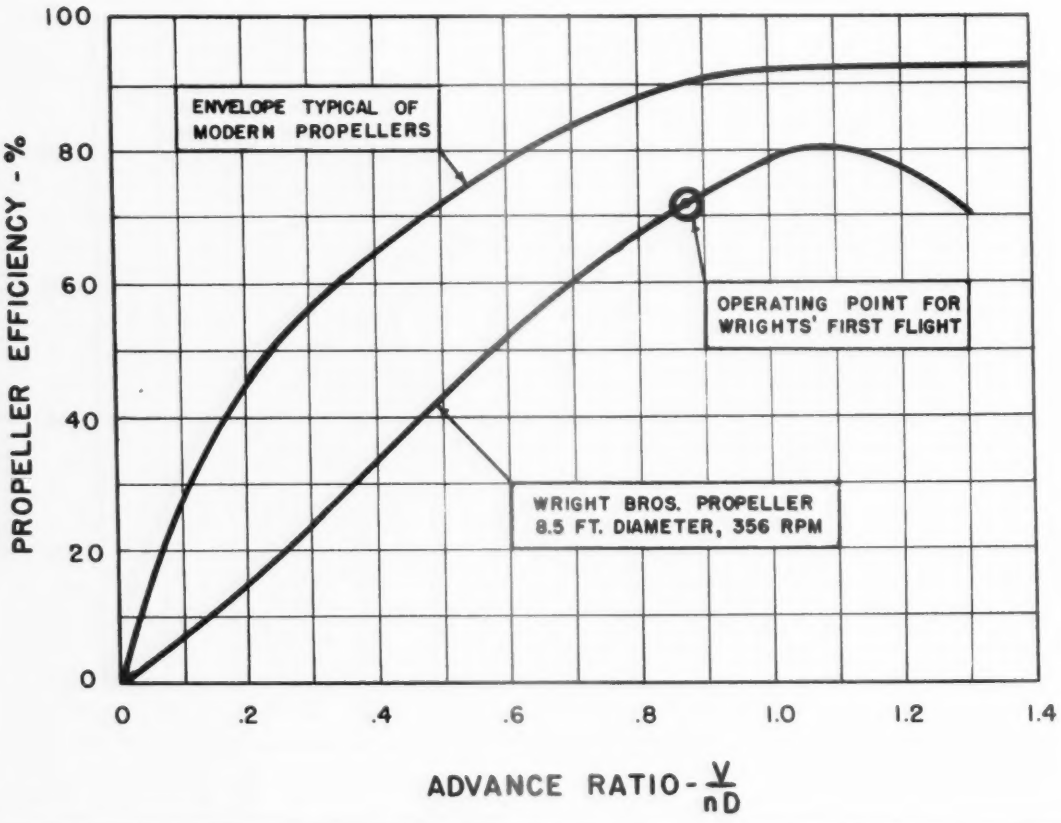
PROPULSIVE SYSTEM EFFICIENCY VS. TIME

ONE WAY TO PRESENT THE TREND OF IMPROVEMENT IN THE PROPULSIVE SYSTEM IS TO CONSIDER THE PORTION OF THE ENERGY IN THE FUEL WHICH IS FINALLY CONVERTED INTO THRUST ENERGY. THE PISTON ENGINES ARE NOT CREDITED WITH THRUST ENERGY FROM THE EXHAUST WHICH IN SOME CASES MIGHT LEAD TO A 20% IMPROVEMENT. THE RAPID IMPROVEMENT IN THE JET PROPULSION ENGINES IS MAINLY DUE TO IMPROVEMENTS IN ENGINE DESIGN BUT PARTLY DUE TO INCREASE IN AIRPLANE SPEED.



AERODYNAMIC PROGRESS IN PROPELLER DESIGN

MOST OF THE IMPROVEMENT SHOWN HERE WAS ACCOMPLISHED IN THE FIRST TWENTY YEARS. CONTROLLABLE PITCH PERMITS THE ACTUAL PROPELLER TO APPROACH THE ENVELOPE SHOWN FOR MODERN PROPELLERS.



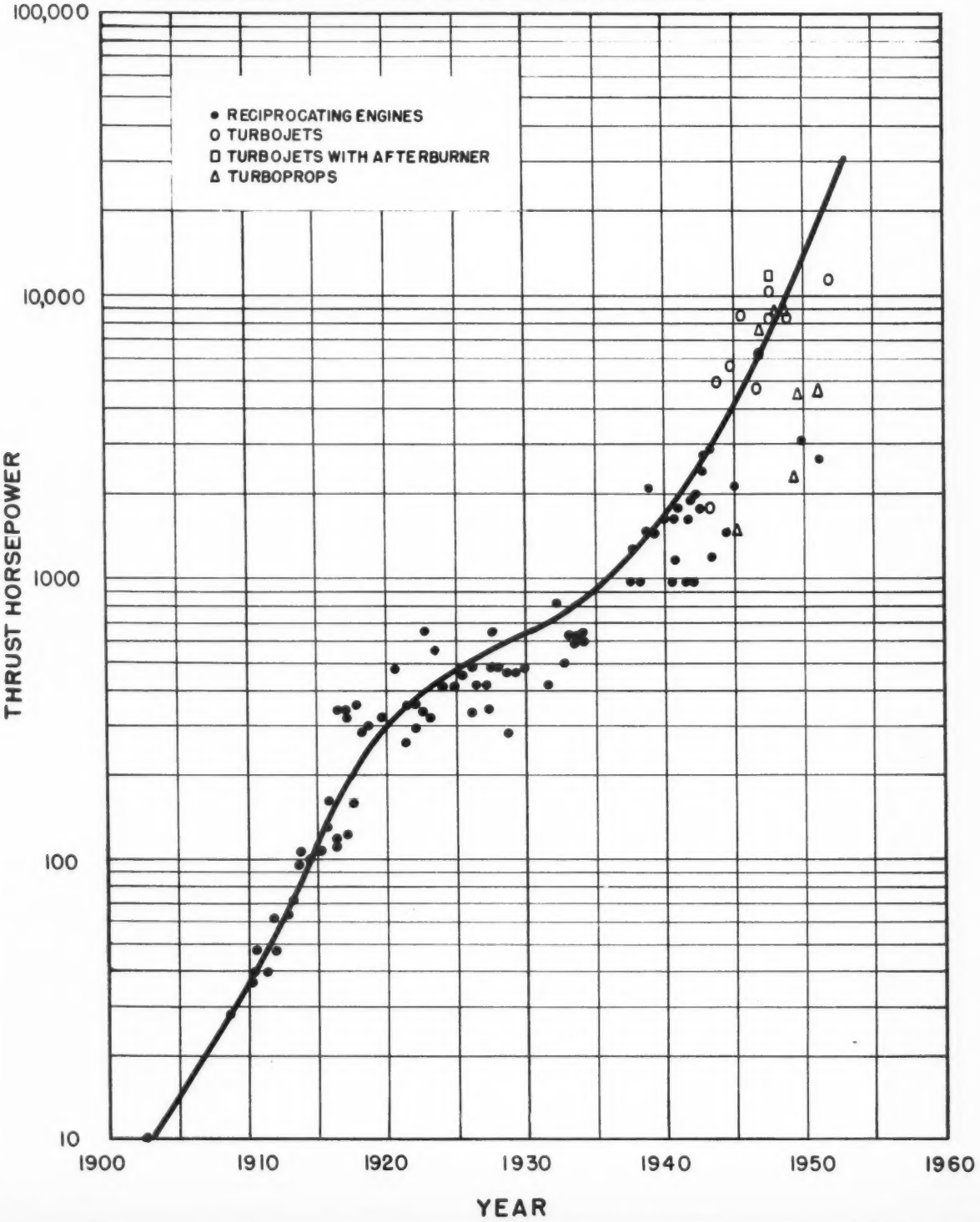
The period from 1920–1930 was a depressed one for the development of aircraft propulsion, as it was for the rest of the aeronautical art. However, developments went forward in spite of this. The work on the controllable-pitch propeller made it evident that the wooden blades were not well adapted for fitting into the controllable-pitch hub, since they required a clumsy and heavy hub structure. Partly for this reason, work was pushed ahead on the metal propeller blade, and this blade reached an acceptable stage about 1923.

The controllable-pitch propeller was still not needed urgently enough to warrant its introduction, and the metal blades were adapted to a simple type of hub whose pitch could be altered on the ground but not changed in flight. This type of propeller was readily accepted in the United States, and by about 1928 it almost completely displaced the wooden propellers for larger engines.

Perhaps one of the most important technical aspects of the engine development of this period was the progress in under tanding the destructive effects of detonation and the setting up of limits in engine design and in operating practices to avoid its occurrence. As a corollary, Tom Midgeley's introduction of tetra-ethyl-

THRUST HORSEPOWER VS. TIME

IN SPITE OF THE LOGARITHMIC SCALE THE POWER OUTPUT OF AIRCRAFT ENGINES SHOWS A STEEP RISE THROUGHOUT THEIR HISTORY. THE LOW LEVEL OF DEVELOPMENT DURING THE THIRTES IS REFLECTED IN THE CURVE OF POWER OUTPUT.



lead additives and various other developments in fuel chemistry opened the way to extensive widening of the detonation-free limits.

The wartime Liberty engine was the principal power plant for most of the American airplanes of the early twenties. However, the Curtiss liquid-cooled D-12 and Conqueror series of engines represented a great forward step in propulsion for fighter airplanes, and these engines, in combination with the Reed metal propeller, largely set the pattern for advanced propulsion of the fighter airplanes.

The re-emergence of the air-cooled radial engine in the later twenties was probably the most significant development of that period. By this time the principles of engineering design and the testing procedures needed for development of reliability of aircraft engines had progressed to a point where it was possible to produce an engine of truly superior dependability.

Perhaps it is fair to say that the power output and reliability of these engines made it possible to think seriously about commercial air transport.

The period from 1930 until the outbreak of World War II was particularly noteworthy for the intensive development of the radial air-cooled engine and the introduction into practical use of the controllable-pitch propeller.

The critical need for this device came into being with the advent of the low-wing commercial transport airplanes, such as the Boeing 247 and the Douglas DC-2 and DC-3. These airplanes had a sufficiently high speed so that the blade angles of the fixed-pitch propellers were high enough to cause aerodynamic stalling of the airfoil sections of the blades when operating under take-off conditions so that the thrust became inadequate for the requirement.

Fortunately, enough background had been obtained from earlier experiments so that it was possible to go into production rapidly with a propeller with two-pitch settings—a low-pitch setting for take-off and a high-pitch setting for level flight.

This was quickly succeeded by the constant-speed propeller in which a speed governor furnishes the necessary signals so that the pitch of the propeller is continually altered in such a way as to keep the engine turning at a fixed predetermined r.p.m. Adjustment of the governor from the cockpit allows the pilot to alter the r.p.m. base in flight to take care of such conditions as cruising, etc.

In many instances the engines used in commercial air transport operate at a better fuel economy at the reduced power output in cruising when the r.p.m. is rather sharply reduced and the power is maintained by the use of a fairly high mean effective pressure. This made it desirable to use a propeller with a greater than normal diameter to suit the cruising condition, and this oversized propeller at the same time increased the take-off thrust so that further improvement in the efficiency of air-transport operation became possible without increasing the basic power output of the engine.

A further development of the controllable-pitch propeller provided for fixing the blade angles with the chord lying along the path of flight so that the rotation of the engine could be stopped in the event of failure of some of the parts and the propeller could be held in such a position as to offer the minimum drag to forward flight. The further extension of the propeller pitch in a negative direction to provide reverse thrust for retarding the landing run did not come into practical use until after World War II, although it was used experimentally some 30 years earlier in 1918.

During the thirties there was an accelerated development of the art of cooling and cowling of engines. The cowling of the air-cooled engine which started out as an external aerodynamic fairing for the engine cylinders gradually became a highly developed metering device for the cooling air designed to carry out the cooling with a minimum drag. Close-fitting baffles were applied to the cylinders, and other precautions were taken to reduce leakage of air that did not participate in the cooling process. Closer cooling fin spacing on the cylinders provided greater heat-transfer surface and reduced the amount of cooling air required. Adjustable exit cowl flaps were applied to permit passage of only the necessary air required for cooling in different conditions of flight and in varying atmospheric conditions.

In 1926, F. W. Meredith pointed out that the radiator for liquid-cooled engines, if properly ducted, could be made to behave something like the modern ram-jet, in that the heated air could be expelled at a velocity somewhat in excess of the airplane speed in spite of some pressure loss in the radiator and that the cooling drag could be eliminated and possibly a little thrust obtained at speeds above 300 m.p.h. This process was followed up in England and later in the United States and proved a valuable aid to airplane performance.

The same approach could be applied to air-cooled engines, but because of the greater pressure losses, the full effect could not be realized until substantially higher speeds were reached.

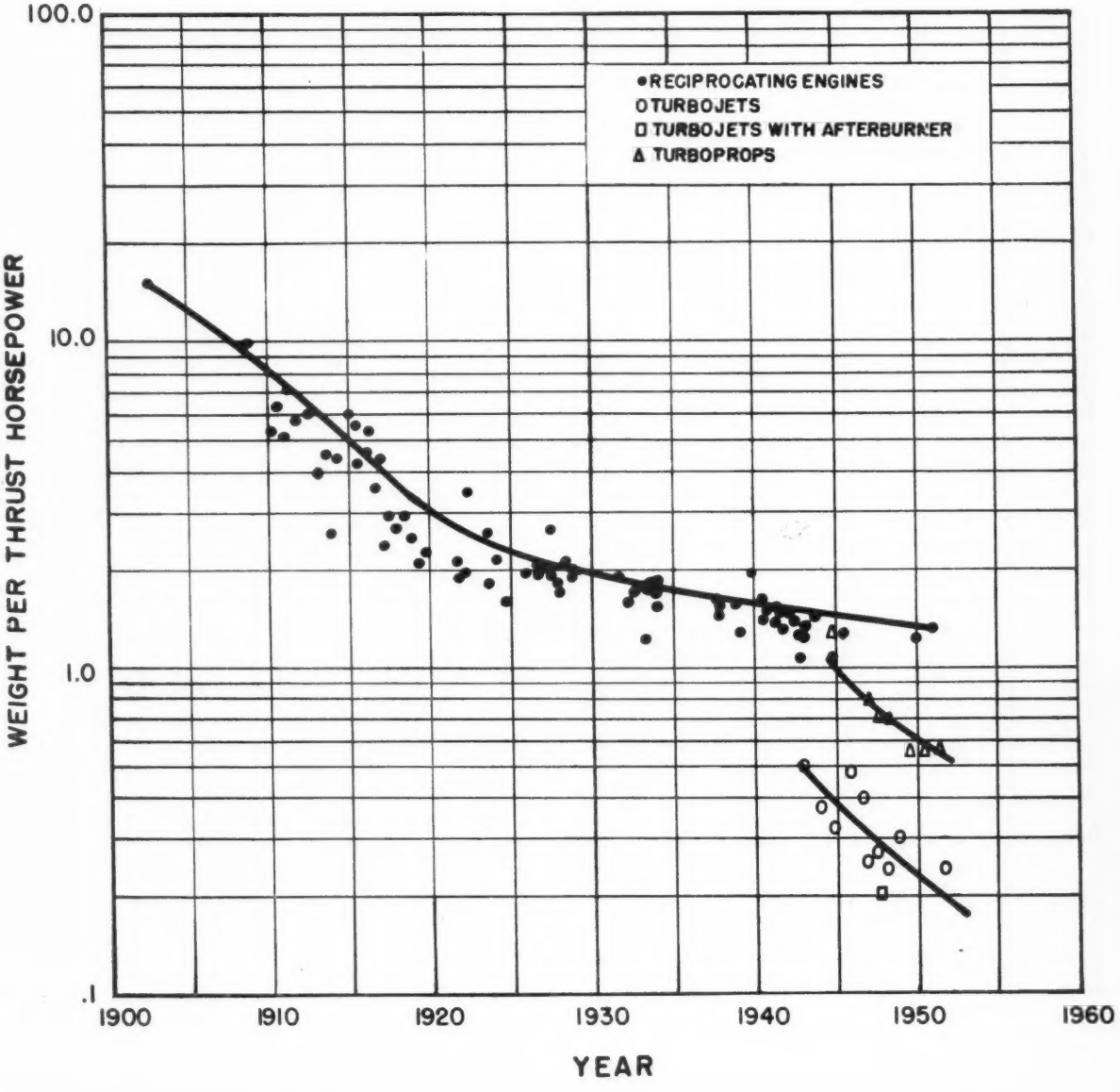
The mechanical engineering part of the engine development which is needed to provide light weight and higher dependability is too big a subject to treat in a paper of this kind. Among the important items were a better understanding of the vibration problems by a study of the various unbalances, the use of dynamic strain gages and vibration displacement pickups and the application of various remedial measures such as the tuned vibration absorber, optimum location of the master rod, and many other ingenious devices and design practices.

One of the important contributions was the sodium-cooled valve, introduced by S. D. Heron. The whole great field of development of carburetors and fuel metering is so highly specialized that it cannot be covered in any detail, but it must be mentioned as one of the major fields of improvement.

As part of the mechanical picture, there was an increased use of component test rigs such as single cylin-

WEIGHT PER THRUST HORSEPOWER VS. TIME

THE WEIGHT PER THRUST HORSEPOWER REFLECTS A STEADY AND CONTINUOUS IMPROVEMENT UP TO THE ADVENT OF JET PROPULSION. IN THIS CHARACTERISTIC THE JET ENGINES SHOW A STARTLING AND ABRUPT ADVANCE.



der testing, gear test rigs, accessory drive rigs, and numerous others. Full-scale testing of the engines was expanded to cover all possible conditions of flight insofar as possible.

On the power-producing side there was a continuous advance in supercharging toward higher mean effective pressure and higher altitude ratings. In general, there was a parallel development of the gear-driven supercharger, both single-stage and two-stage, and the exhaust-turbine-driven type.

Most of the improvements brought about were the result of continuous refinement and evaluation rather than the design of basically new types of design. Indeed, two of the best piston engines in use today have been under development in the same basic configuration for about 20 years and have reached more than a threefold increase in power output as the result of intensive development.

One of the interesting events of the thirties was the jet propulsion power plant of Campini in Italy. This arrangement made use of a piston engine driving a large compressor, heat being added to the compressed air before it was ejected in a rearward direction. Because of the large mass of air handled, this scheme had the inherent possibility of good fuel economy and, with good design, might have shown an overall efficiency somewhat better than the normal propeller at air speeds above about 350 m.p.h. However, the Campini device could not show any substantial advantage over the conventional piston engine and propeller in terms of weight and compactness for a given power output so that this line of approach was not followed up to any extent.

World War II brought many improvements in reciprocating engines and propellers in the way of increased performance at high speed and altitude, with a great deal of emphasis on improved finning and cooling of the air-cooled engines and a great advance in supercharging, particularly with the aid of the turbosupercharger. There was also a marked improvement in fuels paralleled by the use of water injection first introduced on a practical scale by Pratt & Whitney Aircraft. There was also a better understanding of the importance of maintaining a low temperature for the charge entering the cylinders as a means of suppressing detonation. This was emphasized by the introduction by Rolls-Royce of the aftercooler, in which the cooling was carried out after the completion of the entire supercharging process, and the scheme of Pratt & Whitney whereby all of the supercharging was done by the turbosupercharger so that no heat of compression was added after the charge passed through the cooler.

An alternate scheme introduced by Wright Aeronautical makes use of the exhaust energy to drive a turbine suitably geared to the engine crankshaft, thus augmenting the power output.

One of the interesting phases of the propulsion developments of this war period was the increasing use of the thrust from the piston-engine exhaust, which in some cases contributed more than 20 per cent of the thrust from the entire propulsive system.

There were also rapid advances in the art of rocketry, particularly in Germany, as applied to missiles and to piloted aircraft, as well as a substantial development of the pulse-jet and ram-jet engines.

The German rocket projectiles as exemplified in the V-2 used against England proved to be rather formidable weapons, and their partial success has stimulated a vast expansion of research in this field. It is impossible to say where this may lead.

The ram-jet engine, which is an extension of one of the earliest forms of jet propulsion, offers an interesting competitor to the rocket in certain areas of flight and could theoretically be a competitor of the turbojet for aircraft speeds greater than twice the speed of sound.

The use of the pulse-jet engine in the V-1 missiles focused attention on this type of power plant and has stimulated research into the whole field of wave engines. Many of the old schemes in this field are being reappraised, and there is a continuous search for, and examination of, new applications of the principles of pulsating flow and the related cycles of combustion.

In retrospect, all of these developments are largely overshadowed by the introduction of the turbojet engine with its spectacular impetus on aircraft performance. While this device was brought into development and use in an amazingly short time, there was, of course, a long history of development which made it possible. In terms of timing, the most important was probably the rapid increase in airplane speed which had just reached about 500 m.p.h. with the piston engines and propellers.

Jet propulsion had been under study for a long time, but it is inherently a wasteful process and it was not thought to be tolerable at the lower airplane speeds from the standpoint of momentum losses. This is perhaps best illustrated by going back to the expression for momentum efficiency

$$1/[1 + (v/2V)]$$

Because of the relatively small mass of air handled by the turbojet, the value of the jet stream velocity v with respect to still air must be very high in order to produce an adequate thrust, and this is particularly true of the turbojet engine whose principal advantage comes from producing very high thrust from a light and compact mechanism. Obviously, the higher the airplane velocity V, the greater the momentum efficiency becomes. While there is, of course, no exact speed at which this becomes acceptable, the various compromises between engine weight and size, fuel weight, airplane range, speed, and endurance seem to point to a speed somewhere around 500 m.p.h. as the speed where the turbojet can be accepted, at least for the shorter ranges.

Practical examples of this were the experiments of Heinkel in 1939, in which the first turbojet power plant was flown in the relatively slow He 178 airplane. The flights were successful, but it was recognized as a misap-

plication of the turbojet principle due partially to the slow speed of the airplane, and the flight failed to enlist enthusiastic support on a broad scale.

It was not until the Junkers 004 engine had made a number of flights in the Me Z62 at well over 500 m.p.h. in 1943 that the jet-propelled airplane was generally accepted in Germany as a valuable tactical weapon.

Perhaps it is not surprising that the Germans should have taken an early lead in jet propulsion because of their flair for research and the prominent place that had traditionally been given to research work over the past half century.

Certainly British aviation owes a great debt to the persistence and technical genius of Frank Whittle. The first flight of the Whittle engine carried out in 1941 appears to have been generally accepted in England at the time as an indication of the potential importance of this principle for high-speed airplanes. By that time it was possible to foresee possible improvements in airplane design which would lead to a sufficiently high speed to make this type of power plant attractive.

The gas turbine as a type of prime mover appeared shortly after the time of the first flight of the Wright brothers, but the efficiencies of the compressors and turbines of the first machines were extremely low and the losses in the burners were excessive. The permissible operating temperatures were relatively low because of the limitations of the materials available. As a result, the fuel consumption was prohibitive.

The period from 1920 onward saw a great improvement in the efficiency and performance of compact centrifugal compressors largely as the result of the intensive development of aircraft engine superchargers, particularly in England and America.

At the same time, the axial-flow compressor was brought to an advanced state of development, notable work in this field being done by Professor Ackeret and the Brown Boveri Company in Switzerland.

The principles of turbine design were developed to a high degree by many workers in various fields.

The art of fabricating materials suitable for high-temperature turbines was greatly advanced as the result of the turbosupercharger development.

All of these things contributed to furnish the background for the turbojet development and were available to the engineers when the necessary advance in airplane performance made the jet propulsion timely.

Once the soundness of the use of the turbojet engine for high-speed aircraft was established, an intensive development covering the entire technology of this type of engine was pressed forward, particularly in England and in America. Perhaps the most rewarding work from the standpoint of fuel economy has been the improvement in efficiency of the compressors and turbines which have now been brought to a high state of efficiency and which made it possible effectively to design the engines for higher compression ratios. The reliability and service life are largely dependent on the burners and combustion chamber, and some fine work has been required in this field.

Unlike the piston engine, the basic design of the turbine engine lends itself to mathematical calculation based on aerodynamic and thermodynamic data. As a result of a large accumulation of data and an extensive use and development of detailed computation procedures, it is now possible to design many of the features of these engines with a certain amount of assurance. Nevertheless, the development problem is by no means eliminated and thousands of hours of testing and modification are still required to provide a serviceable engine.

There has been a general impression on the part of some people that the fuel consumption of the jet engines will be drastically reduced as time goes on. There are a number of fundamental reasons why this is unlikely to take place and why the engineering specialists in this field do not foresee any drastic improvement in fuel economy.

The two major sources of loss in the turbojet propulsion system are the waste heat in the jet stream after it has fully expanded and the kinetic energy in the stream represented by $Mv^2/2$, where v is the velocity with respect to undisturbed still air.

We may think of jet engine development as starting out with an extremely low compression ratio but with a fixed limit on the turbine inlet temperature due to the tendency of the turbine blades to become plastic and stretch at high temperature.

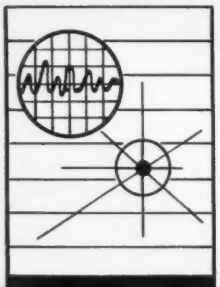
If we now progressively increase the compression ratio while maintaining good compressor and turbine efficiency, due to the higher compression, the temperature of the air will increase at the burner inlet before any fuel is burned. Consequently, less fuel per pound of air can be burned before the limiting turbine inlet temperature is reached. If this process is not carried too far, the heat lost in the exhaust will be reduced due to the higher overall expansion ratio following from the increased compression ratio. At the same time, the kinetic energy loss will be reduced, since the velocity of the jet stream will be lower due to the fact that we have burned less fuel per pound of air.

Obviously, this process cannot be carried too far because the increase in compression ratio would finally lead to a temperature so close to the turbine inlet temperature that only enough fuel could be burned to overcome the internal losses in the system with very little energy left over to produce thrust.

Somewhere between these extremes of compression ratio there is an optimum determined by a number of involved internal conditions. Once this optimum is reached, there is no clear path leading to any substantial improvement in fuel consumption.

We may now consider what could be done if the turbine inlet temperature could be raised either by the use of improved materials or by cooling the turbine blades and other parts. If more fuel were burned without increasing the pressure ratio, the velocity of the jet stream would increase without a compensating improvement in the thermal cycle.

(*Continued on page 131*)



INSTRUMENTS & EQUIPMENT

Instruments and Control of Flight

By Preston R. Bassett

With Sperry Gyroscope Co., Div. of The Sperry Corp., since 1914: Research Engineer, 1914; Chief Engineer, 1928; Vice-Pres. in Charge of Engineering, 1929; Vice-Pres. and General Manager, 1932; and President, since 1945. Also, Vice-Pres., The Sperry Corp., since 1945.

AN AIRPLANE IN FLIGHT consists of three vital components: (1) the structure or air frame, (2) the power unit, and (3) the control system.

I am using the term "control system" in its broadest sense as including the human pilot and all the instruments or servos that aid him. Together they make up a control system that has grown to be by far the most intricate of the three components. Less has been written about the development of this control system than about either the air frame or power units, probably because the human portion of this control system, being mobile, always walks away from the rest of the gear as soon as the airplane lands and is consequently overlooked as an integral part. Furthermore, he properly considers himself beyond the reach of the design engineer. He can't be changed. That fact is the basis of our story. Since he can't be changed he has to be supplemented. The 50 years of flight have been full of excitement in finding ways to aid this unchangeable servo model so that he could undertake greater and greater feats of performance as the airplane and its power unit gave him ever expanding horizons. The development of these aids is the subject of this article. We can start from scratch, since the Wright brothers and the other early pioneers carried no instruments.

It has not been until fairly recently that the performance of a human being has been broken down into understandable mechanistic terms. In fact, it was the perfecting of closed-loop servo systems and the understanding of the theory of such systems that created a vocabulary and formulas for automatic performance which could then be applied, not only by analogy but by fact, to the performance of the human as a servomechanism. This field, now known as Cybernetics, has become of great importance although it is only 10 years old.

The most important part of the complicated human servo system is the visual feedback or, as it might be defined, the continuous visual appraisal of the progress of his performance. When a human performs any such simple act as picking up a pencil, the function of the eye or visual feedback is to measure continuously the relative positions of the hand and the pencil and to give orders to the hand that guides it to the pencil by reducing the error between them to zero. From picking up a pencil to juggling three balls is only an increase in the difficulty of the act but in no way changes the human servo function of eye-muscle coordination. It is again no change of method of functioning to go from juggling three balls to piloting an airplane by visual appraisal of the position and speed of the airplane with respect to the ground and the horizon. It would be as hard to analyze in detail the individual steps of this performance as it would be to analyze the performance of the

juggler. The reason is that the eye-muscle coordination that has been evolved over millions of years has become so perfected that it is completely integrated. Many items of information are taken in simultaneously by the eye, and many simultaneous commands can be issued to the various muscles, not only coordinated with each other but controlled with such perfect negative feedback that there is no undamped oscillation or overshooting in the carrying out of the orders. And so the Wright brothers and the other early pioneers all found that their own servo capabilities were quite adequate to cope with the control of an airplane in three-dimensional flight. A little practice made them extremely skillful.

The first instrument that was carried by the pioneers was a tachometer to give engine revolutions. This was the only piece of information which could not be acquired through the normal senses and which was needed as a measured quantity—r.p.m.

All the complicated orientation information in all three axes was easily integrated by the pilot's normal ability to visually relate the airplane's motion and position to the ground. But that was only as long as he was hedge-hopping. The very freedom that flight gave to the pioneer made it possible for him to move up out of the environment in which his senses had been developed. Flight quickly introduced factors outside of the possibilities of his unaided senses.

As soon as altitudes of more than a few hundred feet were attained, it was found that the human estimate of height was very poor. This, of course, is due to the fact that stereoscopic vision is ineffective beyond about 100 ft. Consequently, an instrument to measure altitude was among the first needed. They did not have to go far for it. It was just lifted over from the balloon basket, since balloonists had already discovered the same need. It was the aneroid barometer calibrated in feet.

The need of the altimeter points up a fundamental weakness in the human mechanism as he enters the unaccustomed environment of being remote from all surroundings. His whole servo system with its visual feedback was evolved for short-distance actions. As long as a man is controlling relatively close objects he can become very proficient. For example, stunt fliers used to perform the feat of flying down over an airfield and picking up a handkerchief from the ground with the wing tip. This meant eye-muscle coordination of the airplane with the precision of inches. It shows that the human servo is unexcelled if it is permitted to function within the distances for which it was developed. The same flier at 1,000 ft. altitude could not estimate his height within several hundred feet.

The next instrument that the pioneer quickly discovered he needed was an instrument for measuring air speed. The wind in his face was not quantitatively precise, nor was he passing by any objects close enough to gage his speed, so he added a simple device consisting merely of a pitot tube exposed to the air stream and a pressure gage that could be calibrated in miles per hour. His need for this instrument at first was much more than just curiosity as to how fast he was going. In these early airplanes there was little surplus power. The pilot had to be very careful to maintain a speed through the air which was sufficient to sustain the airplane. If this speed were not maintained, the airplane would literally sink. Consequently, this instrument, when first placed aboard airplanes, was called a "buoyancy meter."

During these early pioneer days, another most natural acquisition was a magnetic compass. Here, again, it was an instrument merely lifted from shipboard to the airplane. It was needed as soon as any pilot attempted to fly from A to B, or even got out of sight of his own landing field. The magnetic compass, however, behaved very poorly in the airplane. In fact, it proved to be quite incompatible. The reason for this is that the simple magnetic compass is not an instrument that can be perfectly balanced. The vertical component of the earth's field which pulls down one end of the needle must be balanced either by a weight on the other end or by making the magnetic element pendulous. In either case this unbalanced weight is, of course, subject to accelerations when the airplane changes course. These accelerations deflect the needle and make the compass very erratic. The attempts to improve this simple device for aircraft use make an interesting chapter of 50 years of experiments and slow improvement—never, however, to be perfected in its original form and now superseded by some form of flux valve compass that has no rotating magnetic element.

Somewhere along the line in these early years, the clock, almost unnoticed, found its place on the airplane. Its familiar face caused no comment or objection. It came to stay.

With these few supplemental aids around him, fastened to convenient struts or tucked into corners where the pilot could occasionally consult them, he was able to push off into the third dimension and to achieve surprising performances. By 1913 he carried the altitude record up to 20,079 ft. and the speed record to 126.6 m.p.h. He made long cross-country flights, and a year later he found himself in the first World War with still so few instruments in front of him that there was nothing called an instrument board. Fully 90 per cent of his flying was still by his direct senses, or, as the parlance of the day called it, he still flew by bird sense and the seat of his pants. Instruments were for reference only, and many bragged that they didn't need them.

World War I came and went with practically no additions to the instruments in front of the pilot. The main progress of the war years was in the realization that these few instruments had to be designed specifically for airplanes to withstand vibration, accelerations, temperature changes, etc. Also, for the first time, they had to be designed for production in quantities. No longer could a balloon aneroid and a marine magnetic compass or even an ordinary clock be used. So during this period aircraft instruments became a separate yet definite branch of aviation

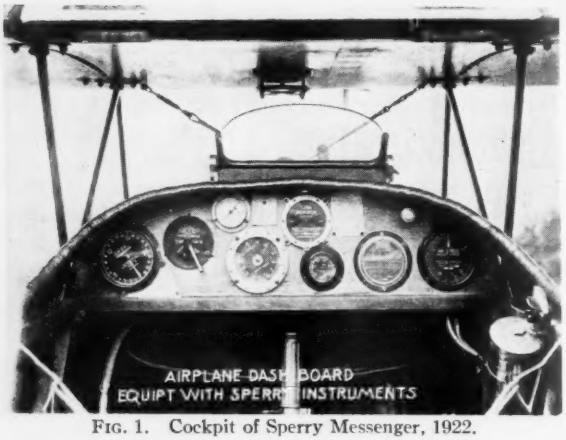


FIG. 1. Cockpit of Sperry Messenger, 1922.

It was, however, some years after the first World War before flying entered the phase that could be called instrument flying. At the time it was called "blind flying." The transition period roughly covers the 10 years between 1919 and 1929. The transition was brought about by the realization of two things. Firstly during the war it was learned that, if a pilot flew into the clouds, he soon lost his sense of equilibrium and was unable to keep control of the airplane. Secondly, after the war was over it was realized that, outside of barnstorming and exhibition flying, aviation would have little commercial use until it could fly reasonable schedules, and this was not possible until airplanes could be flown day or night through any weather—that is, without visibility. The fair-weather carrying of air mail had been tried and failed because of lack of regularity. Consequently, during the early 1920's the complete progress of commercial flying hinged upon extending the instrumental aids to the human pilot.

The first and most important step in this direction was the development of the gyroscopic turn indicator. This was begun in 1918 by E. A. Sperry and was first flown that same year by his son Lawrence. The fundamental difficulty in flying without visibility of the ground or the horizon was the inadequacy of the magnetic compass and the inability to fly a straight course by its indication. The accelerations caused by this erratic course on the magnetic compass produced increasing errors so that the flight course became negatively damped with increasing oscillations until either the pilot became completely lost or the airplane went out of control.

The gyro turn indicator was developed initially not as a separate flight instrument but as a supplementary device to serve as a "crutch" for the magnetic compass. By flying a straight course by the turn indicator, the magnetic compass would settle down so that the pilot could then take a significant reading of his compass bearing. These two instruments remained together for many years. They are an excellent example of complementary instruments. The turn indicator, however, proved so valuable in blind flying that it soon came to be considered the basic blind-flying aid.

Being able to hold a steady azimuth without outside reference immediately made it necessary to control the other axes without outside reference. Hence, another instrument was developed at about the same time which was called the rate-of-climb indicator. It was a direct descendant of the bubble statoscope that the balloonists had used, but it took the form of a dial-and-pointer instrument for aircraft use and was mounted on the expanding instrument board alongside of the turn indicator.

A banking indicator was added to the turn indicator to indicate the proper lateral attitude of the aircraft. This was a ball in a curved glass tube of liquid. So, in the early 1920's, it became possible for the human pilot, by dint of much practice and skill, to learn to fly blind by means of this small group of instruments. Fig. 1 shows a blind-flying instrument board of 1922.

The future hope of commercial aviation appeared to depend on the successful flying of air mail. This success, measured by the percentage of flights completed on schedule, had to depend on the pilot's ability to fly blind. The instruments available were barely adequate and for the first time in the progress of flight control the human mechanism, in attempting long blind flights, undertook more than he could accomplish. There was no margin of safety. It was a courageous undertaking.

Instead of the integrated normal input that visibility gave to the pilot, there was now interposed a series of dials and pointers to bring each piece of information to him by means of a separate indication. This information had to be scanned in sequence by the pilot's eyes. Each dial had to be recognized, read, interpreted, and then, through control action, corrected. It is hard to realize how the simple substitution of instrument indications in place of the normal picture complicated the human servo problem. The early years of blind flying are full of the stories of pilots reporting that their instruments suddenly all went "haywire" and that they had to bail out. The failure was not in the indication of the instruments but in the pilot's appraisal of the situation. The pilot, either because of fatigue or because of turbulent air, was unable to integrate the situation by the piecemeal method rapidly enough to make the proper corrections.

Some of the more skillful air-mail and military fliers of these years worked over this problem and came up with various schemes of simplifying and organizing the task. Probably the most successful of these schemes was developed by Howard Stark and was called the "1-2-3 method." It consisted of making the corrections in a preferred sequence: (1) center the turn indicator (2) center the banking indicator, and (3) correct the air-speed indicator. There were many books written, and courses of instruction given, on this difficult type of flying. Those who studied and trained in this new art became proficient enough to do a creditable job. The Department of Commerce established a special rating for instrument flying. But even so the pilots still sat on parachutes, and it was not considered safe enough to carry passengers as a regular service.

In 1927, when the airplane could stay aloft for 40 hours, the state of the art was advanced sufficiently so that skillful pilots such as Lindbergh, Byrd, Chamberlin, and many others made important flights, but they merely pointed the way. There was still little margin of safety, and many long distance flights ended in disaster because of weather. The situation was still critical.

In 1928, the United States Department of Commerce issued an informal plea to the aircraft instrument makers to try to improve the situation. The directors of the Daniel Guggenheim Fund for Aeronautics established a project for investigating and solving the problem. The result of an intensive year's work by the instrument companies and Lt. James H. Doolittle who had been assigned to head the Guggenheim project, was several new instruments and a new technique. The instruments were the gyro horizon, the directional gyro, and the sensitive altimeter. With these instruments Doolittle found it very simple to fly without strain and to maneuver extensively without visibility. By further addition of a radio localizer and radio marker beams he was even able to take off and land without outside visibility. His first successful performance of this feat on September 24, 1929, is an important milestone in the progress of instrument flying. (Fig. 2.)

FIG. 2. Cockpit of Doolittle's experimental blind-flying airplane, 1929.

The contribution of the gyro horizon and directional gyro lay in the fact that they indicated angular displacement directly instead of by measuring rates. The direct indications in all three axes had no time lags and were much easier for the pilot to interpret. It gave the pilot continuous indications of the true frame of reference in which he was flying and the relation of his airplane to this frame of reference.

The new flight instruments made possible another series of spectacular long-distance flights, culminating in the flight around the world by Post and Gatty in 1931.

The new flight instruments became standard throughout the world. In 1933, the United States Department of Commerce gave air lines permission to fly passengers under instrument conditions. The pilots abandoned their parachutes, and air transportation entered its major period of expansion.

The human pilot could now cope with instrument flying with ease, but the larger airplanes, with their greatly increased range and therefore longer periods in the air, introduced new problems for the pilot. First was fatigue. Then there were the added duties of navigation and computation, communication, and traffic problems. Radio instruments, knobs, and switches spread out up onto the cockpit ceiling. Engine instruments doubled and quadrupled as the airplanes became multiengined. All in all the pilot was again being crowded. His attention had to be distributed over an ever broadening list of duties.

It was quite logical that the automatic pilot at this point might be the answer to relieve the pilot.

It has been impossible to treat of the evolution of the automatic pilot along with the development of the airplane instruments, for, even though they have developed side by side, their stories are entirely different. But by 1933 the automatic pilot started to be an important factor in both commercial and military aviation; therefore it is necessary at this point to go back to the first automatic pilot and bring it up to date.

The first surprising fact to note is that successful automatic flight was accomplished even before the first flight instrument was ever mounted on an instrument board. However, this head start profited it not at all. For 20 years after its first successful flight in 1912, it played no important part in aviation, whereas in those same 20 years aircraft instruments developed from nothing at all to the highly successful assemblage that was overrunning the instrument board. What was the reason? Primarily, it was that the human pilot proved to be such a reliable and flexible servomechanism that the use of a mechanical servo was not warranted in ordinary flying. It meant extra weight, and it was not maneuverable. So even though Sperry produced and flew an automatic pilot in 1912 and won a prize in Paris in 1914 for its outstanding performance, it found no use in World War I. (Fig. 3.)

Its possible use in an unmanned airplane or guided missile was envisioned as early as 1915, and as a secret Navy project it was successfully developed by 1919—too late to be of use in World War I.

During the 1920's it was found to be useful in unmanned artillery target planes and for other odd jobs. But it was not until the advent of the long-range multiengined air-transport plane and bomber that it really filled a need.

In 1933, Wiley Post demonstrated that the automatic pilot was an essential device for long flights when he made the first solo flight around the world with its aid in 7 days and 18 hours. (Fig. 4.) From that time to the present, automatic pilots have been in widespread use both in commercial and large military planes.

The first half of the 1930's were the great years for air transport. Almost by magic many entirely separate advances began to fall together to make a new picture—"by magic" because it all happened during the

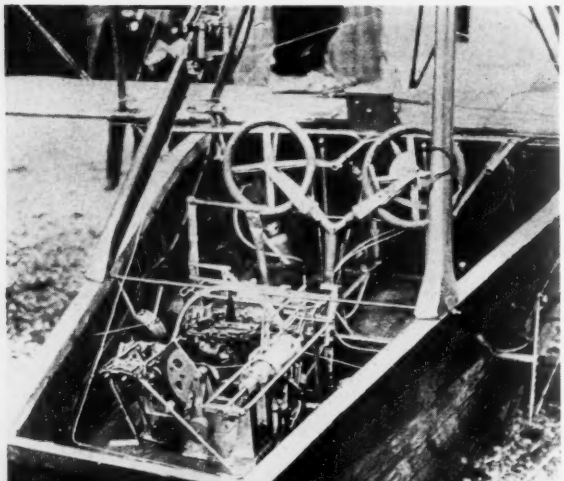


FIG. 3. Gyro stabilizer in Curtiss Flying Boat, winner of French Safety Prize, 1914.

worst years of the world depression. Large all-metal low-wing monoplanes appeared which set new patterns for air transportation. The radial air-cooled engines gained ascendency and rapidly increased in horsepower. The flight instruments became adequate with the addition of the new gyro instruments. The automatic pilot became available as relief.

In addition to these factors, the new field of radio aids to navigation was rapidly developing. The pilot had available several different sources of information as to his geographical position. At last he was definitely tied into the ground. First radio direction finders, then the aural or A-N beacons, and later the beacon indications were made visual, and the direction finder was made automatic. No longer did he have to rely on the combination of visibility and dead-reckoning to determine his whereabouts. Adding all of these advances together makes it evident how the 1930's ushered in air transportation as a full-fledged industry in spite of depressions, economy programs, and financial caution.

By 1939, the entire world was interlaced with airways over which hundreds of great air liners of many nations were flying daily schedules.

By this time all of the items of information that a pilot could want were displayed in one or more indications on his console. The problem had become one of how to reduce the total number of dials either by elimination or combination. Elimination proved unfruitful, since no one seemed to be willing to part with an old friend. In the interests of safety this was wise, since the older instruments, such as the turn indicator and magnetic compass, are now the standby instruments for double-checking or use in case of failure of the prime instruments.

This left the possibility of combining instruments. Combined instruments have a long history, mostly of failures. Many clever designs have been made to consolidate two or more instrument movements in the same container and to produce several indications on the same dial. The results were costly, both in initial expense and in maintenance costs. The resulting indications were clumsy and often confusing. Only one survived, the cross-pointer meter for instrument landing, which consisted of two identical meter movements working in two different axes. Since 1945, however, the entire field of combined indications is up for reconsideration. The availability of small precise self-synchronous repeaters makes it unnecessary to combine the instruments themselves; only the repeater indications need to be combined.

An excellent example of this new approach to combined indications is the radio-magnetic indicator. This consists of a compass card repeater from the Gyrosyn, which rotates against a fixed lubberline, and two pointers each repeating the azimuth of a radio station from two separate automatic direction finders. From this single face the pilot can read his own magnetic heading and the true magnetic bearing of two separate radio stations from which he can get cross bearings.

Other combinations of repeated indications will undoubtedly be found useful, but there is always danger of going too far. It has been found that too many indications on one face can be more confusing than the same number separated.

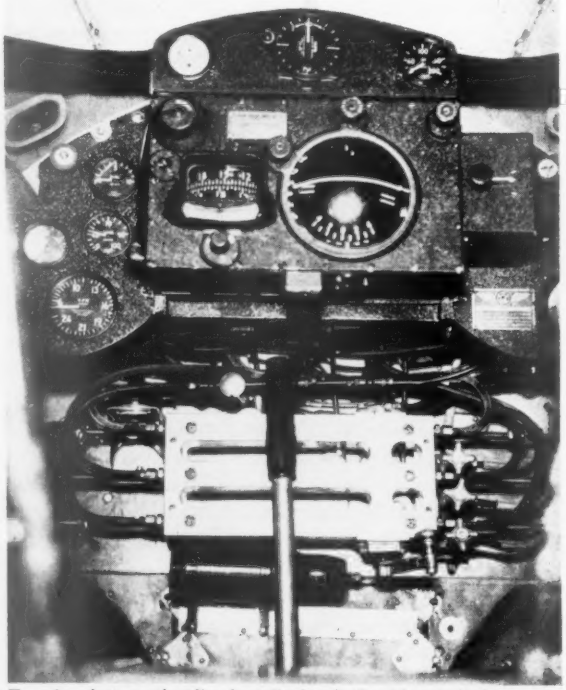


FIG. 4. Automatic pilot installation in Lockheed airplane used by Wiley Post in his solo flight around the world in 1933.

When World War II came, the progress of the previous 20 years was put to the test. It stood the test well.

Looking back at the years 1940 to 1945, it is interesting to see how rapidly instrument production was expanded from the comparatively small demands of peacetime aviation to the huge demands of the great air forces of the war. As during the first World War, however, the accomplishments of these years were not in the creation of new instruments but were in the complete redesign and retooling of existing items for production on a vastly larger scale. The aircraft instrument industry became a production industry.

In addition to the mere increase in quantities, another new trend appeared during the war years. It was brought about by the initiation of countless research projects to make scientific studies in many unexplored fields. In the field of the human pilot and the flight instruments, professional psychologists and aeromedical doctors made statistical studies on fatigue, pilot errors, instrument legibility, eye motions, training devices, simulators, and many other related topics. Much new knowledge came from this approach, which had its effect on the standardization of instrument markings, scale graduations, instrument board arrangements, rational cockpit arrangements, handle locations, and knob shapes for tactile recognition. This type of work has continued since the war and is now considered an important phase of all man-machine problems in the cockpit. It is a significant indication of the maturity of the field when it reaches this last refining phase.

There was one phase of flight, however, that seemed far from a final state—that was instrument landing. In spite of the great effort put on it and the numerous systems proposed during the decade of the 1930's, the practical results never lived up to the promises.

In 1929, it did not seem to be too difficult to go from blind flying to blind landing. Doolittle proved it possible as part of his flight demonstrations of that year. By the aid of a radio localizer and two radio marker beacons, he was able not only to approach but to make contact with the runway while under the hood. In 1932, Captain Hegenberger of the U.S. Army Air Corps accomplished the same thing at Dayton, Ohio, with a slightly different technique, using a radio direction finder.

Even now, more than 20 years later, these performances remain stunts that have been repeated only for experimental purposes or in case of extreme emergencies. It has never become a normal operation.

Today we prefer to speak of instrument approach rather than blind landing, and in the difference between these two terms lies a vast amount of experience.

During the war years the landing problem became critical. Bringing military airplanes back home from missions after the weather had closed in brought much bitter experience and caused a great increase in the efforts to solve the problem. Development of instrument landing systems (ILS) was accelerated. The ground controlled approach (GCA) system was developed. Experiments were made to tie in the automatic pilot to the localizer and glide paths, permitting automatic approach. All of these efforts helped in the war emergency. But what was useful in wartime emergencies was far from adequate for commercial flying. So the problem still stood on the books in 1946 with the highest priority, and since then much progress has been made.

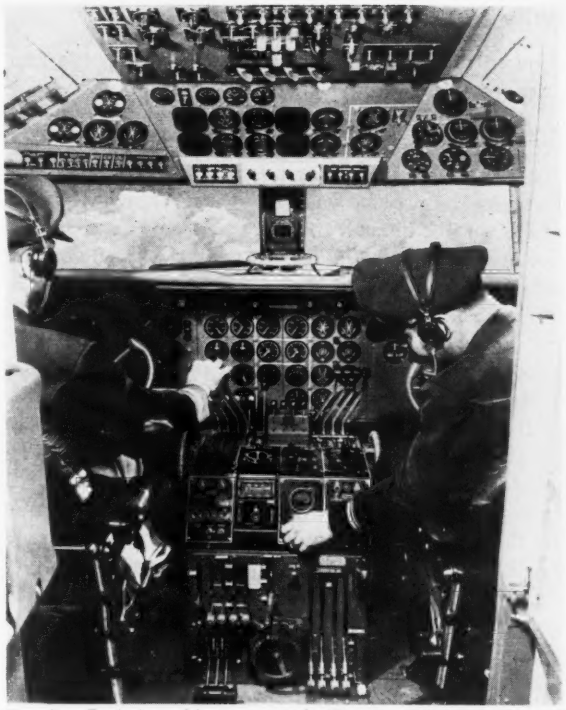


FIG. 5. Cockpit and instruments in Douglas DC-6A air liner of American Airlines.

Since 1946, the automatic approach coupler has been perfected so that it can now control the automatic pilot to bring an airplane down the localizer beam and glide path more smoothly and accurately than can be done by hand.

In addition to the automatic approach, however, much work has been done to improve the human pilot's ability to make instrument approaches. It has been a problem of presenting to the pilot the complex of essential information he needs in such a simplified form that he can respond to it without lag or confusion.

Out of these studies has come a new instrument, the Zero Reader,* which is so different in concept from all previous flight instruments that it becomes the first of a new class that can be called a flight director type of instrument. The fundamental difference between this and all other flight instruments lies in the fact that it conveys no specific information to the pilot as to the attitude, motion, or position of the aircraft. Instead it directs him as to which way and how much he should move his controls to perform some predetermined task.

* Registered Trade Mark.

(*Continued on page 133*)

Why 1903? (*Continued from page 41*)

tion to their goal of human flight. Having the right idea for control was never enough to achieve it.

Why then did the world wait until 1903 for the Wright brothers to succeed where others had failed? There must be something fateful about this particular date, for the airplane was born at just the right time and place for its intensive development by an industrial society ready with the needed technology. Before the availability of the internal combustion engine, the Wright's invention would have been nothing more than an improvement in gliders. Before the availability of gasoline, this engine was a cumbersome curiosity, fueled from a gas bag or with expensive benzine.

But the new century had hardly begun when the first great oil gusher was blown in near Beaumont, Tex. Nothing like Spindletop had ever been seen before. A granite shaft now bears this inscription: "On this spot on the tenth day of the twentieth century a new era in civilization began." After Spindletop, the new oil industry supplied cheap and abundant energy and ushered in the machine age.

The Wrights found the marine propeller ready for adaptation as an airscrew. Alloy steels and aluminum were soon to replace their original wood and wire structure. Precision tools and the manufacturing techniques of the automotive industry led to quantity production. Then came radio and Elmer Sperry's gyros and autopilots to aid navigation and to extend the pilot's ability to fly long distances in all weather. As a consequence civil air transportation began to span continents, and then oceans, until a world-wide pattern of air routes resulted.

Installation of machine guns and bombs created the military airplane, and Air Power became the serious concern of great nations. Their rivalry accelerated research and technical development.

The new century was also ready with scientific resources never before available. The rapid development of the Wrights' airplane was guided by scientists and engineers into the safe swift vehicles of the air that we use today. A new servant of society emerged, the aeronautical engineer, charged with the application to the airplane of the arts and sciences of his time. But he had roots in the nineteenth century.

By 1903, the classical sciences of elasticity, dynamics, and hydromechanics were ripe for application to the airplane's structure, to its stability and control, and to create the new art of aerodynamics. Some of the scientific pioneers should be remembered, such as: Joukowski and Riabouchinsky in Russia, Marey and Eiffel in France, Lanchester and Bryan in England, Kutta and Prandtl in Germany, Levi-Civita in Italy, and Chanute and Zahm in this country. A complete list would be long and international.

The airplane was born not only when science and technology were ready for it but in an especially favorable social climate in the United States. The year 1903 was a time of enthusiasm for new ideas. Our Spanish War was over and the country was expanding. Applied science had been producing successive marvels—the telephone, electric light and power, alloy steels and machine tools, aluminum, gasoline, and the automobile. The airplane was naturally exciting and popular. It represented the realization of an age-old dream.

Public support, in war and in peace, has poured money and effort into the development of the Wright invention such as no other invention has ever enjoyed. Sir Richard Fairey in his Wilbur Wright lecture of 1950 calculated that up to 1948 there was spent on aviation, world-wide, the equivalent of 256 billion U.S. dollars.

I have tried to explain what the Wrights did and the peculiar circumstances that made what now seems simple so exceedingly difficult. Then I have mentioned the favorable technical, scientific, and social climate at the beginning of this century. Why did the airplane, that was for a long time nearly ready, wait for 1903?

A student of the history of technology may well wonder whether there be some combination of circumstances, a parameter of hidden cause, which brings forth an innovation when the state of the art makes it possible and when the state of society is ready to welcome it. The Monitor appeared in our Civil War when needed; the bomber and the tank in World War I; radar and the atomic bomb in World War II.

A seed does not sprout and grow until both the soil and the season are right. We can have only hazy notions about where the seeds of great inventions may lie during long fallow periods. We observe that, when the state of an art advances, important inventions appear. When an art is static, inventions tend to be trivial. Great inventions come along with the great tides of economic and social change. The first half of this century has been marked by such a tide, with the internal combustion engine, the automobile, and the airplane riding it.

For the next half century, let us hope that the universal use of the ocean of air, first opened to mankind by the Wrights, may lead to a better world order and to a magnificent advance in human welfare.

Design of Military Aircraft (*Continued from page 49*)

maximum progress. The Air Force, for example, could have demanded a Mach 1.5 fighter in 1940 or could today demand a Mach 4 bomber. However, it is doubtful whether such requirements would greatly expedite the technical innovations—of a jet engine and a few aerodynamic miracles for the fighter and of advanced thermodynamic technology for the bomber—which must precede their design. Meanwhile the force in being would suffer. The step is too long. Conversely, the Air Force, or any air service, must constantly guard against the temptation of too short a technical step, with all the attendent lures of quick delivery, low cost, and maximum force in being.

This relationship between design technology and military requirements largely determines design trends in military aviation. On one side is the designer saying, "this is what we can give you," and on the other is the military service saying, "this is what we want." The direction and length of step taken by the designer are influenced vitally by the military requirements, and conversely the formulation of military requirements is certainly affected by what the designer has already accomplished and by what he claims he can accomplish next.

The Development Cycle

When the Wright brothers and their early competitors went to the services, they found, of course, that no military requirement existed to utilize their crude flying machine. Eventually they managed to get a few experimental units into military test, and thereafter the military gradually learned to use, and even more gradually to understand, the new device. Thus began the first cycle of military aeronautical development, with the services feeding back to the designers their desires for adaptation of the flying machine to perform contemplated military missions.

The cycle of development can be likened to a simple closed-loop servo-actuator system. The performance of today's aircraft is being weighed against present and anticipated military problems, and the deficiencies or error signals are being routed through analysis and eventually fed back to the designer in the form of requirements for tomorrow's operational aircraft On an average, the cycle takes about 5 years, as illustrated by the fighter trend from the P-51 to the F-86 to the F-100 or by the bomber trend from the B-17 to the B-29 to the B-47 to the B-52.

Now a closed-loop servo system may be unstable if there is overamplification of the error signal or an excessive time lag in getting the signal around the complete circuit and back to the point where it results in a correction of whatever you are trying to control. If the signal is strong enough and the time lag great enough, the result is oscillation becoming progressively more violent.

Certainly in our analogy this potential weakness exists, since the error signal feeding back to the designer can be very strong indeed, and the whole cycle takes a rather long period of time. We might therefore expect some serious oscillations in design trends

A typical example of the dangers of the system was the recent demand for a lightweight fighter. The cycle started when F-86 met MIG-15 in Korea. Being lighter, the MIG-15 displayed an advantage in certain phases of high-altitude performance. Over a period of several years, an error signal fed back through the system, in effect conveying the information that our fighters were too heavy for MIG alley and that we must have lightweight fighters. Let us suppose, for illustration, that this particular error signal had resulted in all-out concentration on lightweight fighter development and production. The resulting airplanes might be available in operational quantities 3 years from now. Let us guess that the Air Force might then be required to fight in Europe under conditions demanding maximum range capability and heavy armament. The lightweight fighter would be found woefully inadequate for this type of operation. So a new error signal would be fed back and overamplified, and an even more violent swing in the other direction would be started. And so on until disaster.

Actually, the oscillations do not become that violent. First, to a considerable extent they are dampened by the wisdom of experienced service personnel, who realize that tomorrow's tactical situation may be quite different from today's and that the only sound course is to keep the whole problem in focus and anticipate it with suitable equipment instead of stampeding in the direction indicated by one limited combat situation. Second, the combat deficiency that produced the error signal can often be reduced or eliminated by the designer through shortcut improvements and compromises to correct the deficiency. In the case of F-86's in MIG alley, this was accomplished by continued refinement of the F-86 series and by several ingenious field changes that reduced or nullified the previous altitude advantage of the Russian design and ultimately resulted in the most extraordinary attrition ratio in the history of air warfare. This left the Air Force free to consider development of a lightweight fighter for anticipated future requirements without the pressure of an immediate combat deficiency.

Another example resulted from the demand for extraordinary fighter range in World War II. I presume I can cite this example, since my own company was a party to the resulting design trend. In response to the desire for a maximum range escort fighter, we came forward with the F-82 Twin Mustang, capable of a combat radius of almost 1,000 nautical miles as compared with the P-51D's combat radius of about 600 nautical miles. We started work on the F-82 prototype design early in 1944. Because of prolonged engine mal-

functions and other problems, the Air Force did not have fully operational aircraft until 1949. By this time the need for escort fighter aircraft, particularly in the piston-engine category, had all but vanished in the wake of the jet revolution. Jet-bomber aircraft were flying high and fast where piston-engine escorts could do them little good. Jet escorts were impractical because of range limitations. The pendulum had swung full arc to the idea of bombers going in undefended, and the F-82 was an anachronism of questionable military value. The aircraft was utilized successfully in the early stages of the Korean war but not in the mission for which it was intended. In fairness to the officers concerned and ourselves, it may be added that early in the program the overswing was perceived, and a large quantity of the F-82's were switched to the night-fighter category.

Looking back over the history of military aviation, the reader can probably find many examples from his own experience where overamplified error signals threatened to produce extreme oscillations in design trends. That this did not occur and that we generally have had the right plane at the right time is a tribute to our Air Force and Navy procurement officers as much as to the ingenuity and foresight of our design groups.

In a sense, each combat problem could be met most effectively by a highly specialized weapon designed for that one job. If it can be predicted accurately where the battle will be fought, what the climatic conditions will be, what weapons and strength the enemy will have, and so on for an infinity of factors, then it should be possible to design, develop, and produce winning airplanes or other weapons for that battle. The French attempted something like this in the Maginot Line. The best that can be said is that it might have been successful had time and technology stood still.

Since the United States must maintain the ability to fight under any set of conditions anywhere in the world, it is obvious that we cannot follow a Maginot Line type of thinking in our military aircraft development. Instead, we must design and build an adequate number of the most versatile aircraft that we can—able to operate in the tropics or the Arctic, adaptable to as many air-combat jobs as possible, and capable of quick adaptation to counter any new weapon the enemy may bring against us. At the same time we must not carry the versatility idea to the point of building a "Jack-of-all-trades, master of none" type of aircraft.

In this 50th year of powered flight, it is easy to look back from the present state of the art and deprecate the crude beginnings made by the Wrights and their fellow adventurer-scientists near the turn of the century. In part, this temptation is a product of the almost unbelievable progress that has occurred in aviation in 50 years; it is hard to believe that so little was known so recently.

The Wright brothers gave us the key to a room that mankind had long yearned to enter. Although anyone can now walk through the door with assurance and confidence, he should carry in his heart the highest respect for the pioneering spirit, determination, ingenuity, and high courage of the men who first crossed the threshold into the unknown.

Evolution of Naval Aircraft, 1911–1954 (*Continued from page 59*)

The Future

There are many indications that within this decade we shall see transformations in naval aviation greater than those of any previous 10 years. We are in a period of superlative progress, both in aeronautical equipment and in techniques of applying it to naval operations.

The modern equipment of our carriers, mentioned above, will enable these ships to cope with the increased minimum flying speeds that the Navy has accepted to reach the goal of supersonic speeds of carrier airplanes. Fighter and attack airplanes of supersonic speed capability and with adequate combat radius can, and will, be operated from aircraft carriers. We shall see fighters in the low supersonic range in the near future, as turbojet thrusts and afterburner efficiencies increase (the F4D Skyray, for example, is by no means at the limit of its development). It is only a matter of time and further power increases until carrier fighter speeds will continue their upward surge.

Attack airplane speeds will eventually follow the supersonic trend, but this increase will probably lag somewhat. The higher military load and greater endurance or combat radius required for the attack mission mean that a supersonic airplane in this class must be large and heavy. The "Forrestal" class carriers will embody all the features necessary for operating these airplanes (with a margin for growth), and it can be expected that their introduction into Fleet service will be timed to coincide with advent of the large carrier.

The modern aircraft carrier and its improved equipment have not been the only objects of recent attention in naval aviation. We can look for development of other means of launching and landing naval aircraft. Mention has already been made of hydroskis on the Sea Dart seaplane fighter with its wide operational versatility. When the hydroski is perfected after service experience, the minimum speed of fighter seaplanes can be allowed to increase, with the eventual result that, for a given engine power, these airplanes might be faster than landplanes of

comparable military characteristics. Conversely, the Sea Dart may be the forerunner of airplanes of lower weight and smaller size than competing landplanes with identical missions. The hydroski seaplane is an especially good naval application for delta wings.

Another possibility of the future which is innately attractive to the Navy is the vertical rising airplane. The problem of vertical ascent can be solved in a number of ways, as we already observe in the "convertiplane" programs. The Navy undoubtedly will benefit from these projects and from others of a more radical nature. For example, we know that, as we approach a Mach Number of 2 in level flight with turbojet-powered aircraft, the available thrust will be sufficient for vertical take-off and landing. Subject to solutions of the stability and control problems, we may have here an indication of a future type of carrier aircraft.

Rotary-wing aircraft hold much potential interest for the Navy as a basic serviceable type, though not high-performing. We can look for important developments in this class, especially for antisubmarine work, air-sea rescue missions from carriers, and observation and utility services for battleships and cruisers. Convertiplanes of the compound helicopter type will be useful in many naval missions, although it is difficult at this time to predict which of the many rotor, wing, and propulsion combinations and arrangements are most likely to be adopted by the Navy.

What of the more distant future? There are many indications of what we may expect. In previous years, both carrier airplanes and seaplanes have suffered performance penalties, when compared with land-based types, because of the high load or strength factors required to permit operation from floating bases or the sea. Naval aviation is finally approaching the point where the performance requirements of the airplane in its natural environment—speed, climb, altitude, range, maneuverability—will dictate the limiting design factors. This means that carrier aircraft and seaplanes will no longer be penalized by design characteristics imposed by the nature of their supporting bases. The future promises even greater advances in both these categories of naval aircraft as research and experience combine to expedite development. Surely we can safely say that the limits of progress are not yet in sight.

Design Trends in 50 Years—Civil Aviation Other Than Transport (*Continued from page 81*)

Questions can properly be raised as to the importance in the future of the turbojet and the turboprop power plants in nontransport civil aviation. Although at present specific fuel consumptions are relatively high, one may feel confident that reductions will take place in the future and that a continuously increasing use of these power sources will take place.

What appears as a desirable compromise is the ducted fan configuration, so far relatively untried but theoretically possessing many desirable characteristics of the engines mentioned above, combined with advantages established in the reciprocating engines in common use today.

(3) *Safety*

The record of safety for planes in the nontransport civil category is good in proportion to the competence of the pilots. Thus, in company and commercial flying (exclusive of crop dusting), the record approximates the excellent performance in scheduled air transports. However, the statistics are not satisfactory at all in the personal flying field—i.e., where the pilot possesses a private flying license only. Taking nontransport civil flying as a whole, we find that fatalities per 100 million occupant-miles was of the order of 200 in 1930, 50 in 1940, and 20 in the early 1950's. This shows steady and substantial progress but is still more than 20 times greater than for scheduled air carrier flying.

Many accident-prevention measures are being incorporated in civil aircraft today, but there are others that might further improve the situation. Particularly desirable would be greater spiral stability to permit hands-off flight should adverse weather be encountered inadvertently, giving assurance that the plane would automatically stay on an even keel. Somewhat lower landing speed than at present is also highly desirable, possibly of the order of 40 m.p.h.

Undoubtedly, however, the best way to improve the statistics cited above would be to design for survivability in case of accident, an area sadly neglected until recently. Of the several features that will enhance survivability, one may mention as most important the use of shoulder harness restraint designed for about 20*g* deceleration, coupled with the incorporation of increased strength in the cabin structure.

For extensive cross-country flying with any expectation of achieving an 80 per cent year-round scheduled-flight-time reliability, the plane must be equipped with VHF radio receiver and possibly other electronic aids to the extent practicable from considerations of pilot competence and pocketbook. Installation of cross-wind landing gear is also desirable.

Although surveys have shown that fear does not hold a high place among the reasons why one-third of those who acquired aircraft in 1946 abandoned their use in one year, it is nevertheless extremely important from

the standpoint of preventing newcomers from entering the field. One may not, therefore, overestimate the importance of improving safety in those areas of nontransport civil aviation where the private pilot does the flying, a "must" in achieving importance for the family plane.

(4) Comfort

Generally speaking, the cabin arrangements of civil airplanes are satisfactory from the comfort standpoint and will be more so if power plants possessing superior smoothness characteristics are used. We are a long way from the helmeted and goggled days of the 1920's, advancing from the open cockpit to the limousine arrangements, particularly in the four-place executive-type planes of today.

Under this heading a brief discussion of noise is in order, since internal sound level is still too high although soundproofing has brought it to a fairly acceptable point. Larger diametered propellers and use of exhaust mufflers and more insulation can furnish added improvement.

In addition, however, our planes of the future must be designed from the "good neighbor" standpoint. This means the need for reduction of noise to people on the ground so that airports may be located closer to town and so that heliports may be located on vacant lots or on the roofs of buildings. Improved engine mufflers and larger diametered propellers can contribute substantially in the fixed-wing configuration. This means gear or belt drives for the engine.

(5) Airports

The 6,000 or so airports now active in the country are fairly adequate for the amount of civil nontransport flying which presently exists. However, the advantages of flying increase rapidly as more and more places to which people wish to go are provided with airports. The need for locating these as near to town as possible has been emphasized and the advantages of roadside landing strips will increase in importance with the more general use of the cross-wind landing gear and of roadable aircraft. There is an analogy here between the number of airports and amount of aircraft utilization (and, hence, production) compared with the historical improvement of roads and the increase in automobile production.

(6) Cost

In recent analyses, many reasons were given for abandoning personal flying, once started. Financial considerations were the highest in percentage. Particularly was this the case for operating expense (as opposed to first cost). The most important factor involved here is hours of utilization during the year. Fixed operating expenses are relatively high so that hourly costs drop substantially as annual hours of use increase. Presently, active personal aircraft are only operating about 105 hours per year, whereas executive types average 255. Acceptable operating costs exist in the latter case but not in the former. Because of these facts, the average holder of private pilot's license usually can do better by renting or leasing a plane than by owning it.

Some reductions in initial price may result from more careful production design, but the real answer here is to increase quantity production, by means of which, given truly large production, prices will drop rapidly. What we need is to start a benevolent spiral of greater utilization followed by greater production resulting in lower cost.

(7) Weather

The magnificent federal airways system providing air traffic control and air navigation and landing aids serves well the pilot of the executive and company-owned plane possessing air-borne equipment to use these electronic facilities and the flying skill signified by a commercial pilot's certificate. But the air-borne electronic equipment and the required competence are not present for the personal aircraft owner having a private license. He may, to be sure, have a VHF radio receiver and possibly omni-range equipment, but he still must completely avoid bad-weather flying in order to be reasonably safe. GCA installations can be used by the private pilot, but an adequate nation-wide coverage of required ground facilities is hardly to be expected for a long time to come.

To expect "victory by electronics" for the personal aircraft owner remains extremely doubtful. Devices such as Teleran (television and radar combined) are one possible avenue of investigation, and the use of transistors may reduce cost and bulk to permit more general use of air-borne electronic equipment. There are also possibilities in connection with autopilot and artificially stabilized aircraft, but for a long time to come it appears that really bad-weather flying must be avoided by the private pilot.

(8) Utility

Usefulness of the nontransport civil airplane is apparent for the forms of flight where commercial pilots do the flying, which represents about two-thirds of the airplanes in this classification. This is evidenced by the extremely rapid growth in purchase and use of aircraft in the business, industrial, executive, and transportation for hire categories. Lack of utilization, however, is the one big stumbling block that must be overcome in order to attract greater personal use of aircraft in which the biggest potential market exists.

As emphasized above, weather is the largest obstacle, with high cost and insufficient safety next. From the above discussions, there appears to be some hope in the adoption of special configurations such as the roadable airplane which will permit a certain degree of by-passing of bad-weather conditions when encountered.

Conclusions

We have come a long way since that first flight by the Wright brothers of their powered, heavier-than-air "Flyer" on December 17, 1903. We have seen that, during the five decades subsequent to that time, the nature of flying has advanced far from the spectacular demonstration and circus flying of the first period; through the developmental flying of the second; the barnstorming and romantic activities of the twenties; the consolidation of the fourth decade; and the greatly increased utilization of flying for nontransport civil aircraft other than personal in the final period. A considerable romantic appeal kept things going well at many times, but in the ultimate we find that adequate utility must exist to justify hope of substantial markets in the personal family-owner field.

And yet, all things considered, one must remain optimistic for the future of all flying, even in the personal aircraft field where there clearly exists a substantial romantic satisfaction and no doubt some day will be an adequate utility.

The military uses of aircraft have increased in importance to the point where air forces overshadow other military arms for defense. Similarly, use of the airplane in scheduled transportation operations of both goods and people is overtaking and exceeding all other means of providing such services because of the inherent advantages of speed and avoidance of ground obstacles, with ever increasing comfort, safety, and reliability.

It is likely that the Wright brothers thought of the use of their invention in connection with personal flying. In later years, Orville Wright frequently deplored the fact that his development had found its chief use for military purposes, although, of course, he was gratified by the ever expanding air transportation uses, which had reached such promise before his passing.

This brief discourse on aircraft design progress and trends, made on the occasion of our celebration of the golden anniversary of powered flight, brings us to the conclusion that our aircraft designers and engineers have evolved useful and economical vehicles in which many civil nontransport services can be performed better than by any other means. All forms of nontransport civil aviation will continue to advance, more uniformly hereafter than in the past, with the family airplane design the largest unfinished item on our designer's agenda as a challenge for the future.

Design Trends—Guided Missiles (*Continued from page 87*)

the missile than do the command or beam-riding systems. However the traffic handling capacity, especially of the active and passive types, is much greater. Furthermore, homing systems become more sensitive and accurate as the missile approaches the target, while the opposite is true for the other systems. It would appear that a combination of simple command techniques for the early part of the flight, together with some form of homing for the latter part, might give a satisfactory compromise between seeker sensitivity, missile complication, and traffic handling capacity.

For targets that are stationary or whose location at the time of missile impact can be predicted, there are a wide variety of conceivable systems. One of the oldest involves the covering of the region to be traversed by the missile with an electromagnetic grid, usually originating from radio transmitters established along an extended base line. The missile contains sensing and computing devices that cause it to follow a predetermined path to a particular set of coordinates defining the target location in the grid. The electronic equipment in the missile may either play a passive role, sensing its location in a grid established by the base line stations, or take an active part in the establishment of the grid through interrogation signals sent from it to the base line stations. These systems are natural developments of the Loran and Shoran systems, which have been employed for years in the navigation of piloted aircraft. One of their greatest weaknesses is their susceptibility to enemy jamming and countermeasures. This susceptibility increases and the accuracy decreases as the target is approached and the distance from the base line increases. A conceptually similar system replaces the electromagnetic grid by the coordinate system formed by the earth's magnetic field. This is much less subject to enemy jamming, but sensing elements of sufficient precision constitute an extremely difficult problem, and the magnetic field must be accurately known both over the mid-course and target areas. There are also variations and fluctuations in the magnetic field which further complicate the problem.

Automatic celestial navigation also provides a means of extending conventional navigational procedures to guided missiles through the use of star-trackers trained on chosen stars by means of photoelectric cells. One of the serious problems, apart from the star-tracker itself, is the determination of the true vertical from observations in an accelerating missile which can indicate only the apparent vertical. Willful jamming of this system by an enemy would be difficult, but, unless flights are made at extreme altitudes, weather can seriously interfere with its effectiveness. Furthermore, the problem of obtaining sufficient accuracy at really long ranges is a formidable one.

A purely inertial system controlled either by integrating accelerometers (like those of the V-2) or by precision

gyroscopes can furnish what is, in principle, the most desirable of all long-range guidance systems. Such a system would be completely independent of weather and immune to jamming or enemy countermeasures, apart from actual missile interception. Unfortunately, the precision required of the components for really useful accuracy is one or more orders of magnitude greater than is now generally available.

In view of the difficulties associated with each of the above systems, it seems not unlikely that the first fully satisfactory long-range guidance system may be obtained by combining elements of one or more of those mentioned with certain other elements of the command or homing systems discussed in connection with maneuvering targets. One thing is certainly clear—guidance is probably the most difficult aspect of the overall problem of producing operationally useful guided missiles, especially for long-range applications.

An attempt will be made, in concluding this paper, to indicate briefly what appear to the author to be some of the major trends that have been revealed by the past history of guided missiles and to indicate certain directions that the future developments might take. One of the most important of these trends relates to the organizational philosophy and setup that have come to seem essential to the successful development of a guided missile. In the past, when a new combat aircraft was to be developed, it was customary for the Air Force to let a series of prime contracts to air-frame, power-plant, armament, and accessory companies. Similarly, in the development of a new type of artillery, ordnance agencies usually authorized a number of independent prime contractors to work on the gun, ammuntion, fire-control gear, etc. The final working out of the operational aircraft for squadron use or of the artillery for battery employment was effected through much give and take on the part of the individual contractors under the monitorship of the sponsoring agency, which retained the final responsibility for meeting the established military requirements. However, a guided-missile weapon system is so enormously complex, and the various components are so interrelated in their effects on one another, that this method of procurement has proved inefficient and sometimes impossible. In its place the concept of weapon system responsibility has been developed. Under this concept the sponsoring agency specifies the military requirements in fairly broad terms and then assigns to a single prime contractor the full responsibility for the development of the complete weapons system to meet these requirements. We have seen earlier that the V-2 project incorporated many elements of this idea, and in the U.S. guided-missile program practically all of the major projects have been developed in this fashion. A large number of new industrial management problems have appeared as a consequence, but the important ones seem to have been satisfactorily solved, since at least in the Air Force, the technique is rapidly being extended to weapons systems other than guided missiles.

Turning from management to technical trends, in the fields of propulsion it has already been suggested that the most important power plants for at least the fairly near future are the rocket and ram-jet. Significant improvements in both are almost certain to occur in the next few years. Rocket size and performance should increase as a result of fuel development, both liquid and especially solid, new materials, better heat-transfer knowledge and techniques, etc. Ram-jets will unquestionably gain in performance, flexibility of operation, and reliability, primarily from new knowledge and experience in the fields of aerodynamics, air-fuel combustion, fuel supply and injection, and materials.

With respect to overall configuration, it seems likely that the general appearance of long-range missiles, both the rocket and ram-jet types, will not soon be greatly changed, although minor modifications will certainly follow from improved structural materials. On the other hand, with increased knowledge of supersonic aerodynamics, it is not unlikely that the appearance of many short-range highly maneuverable missiles will be greatly altered.

In the field of guidance, it is probable that most of the fruitful lines of approach have already been considered and studied. Progress during the next few years is apt to be primarily in more appropriate combinations of different techniques, in refinement and improved performance of components, and, perhaps most important of all, in improved reliability.

The simplest guided-missile system is extraordinarily complex, and there is woefully little operational experience on any current missile. The background of field experience should expand greatly in the near future, and this must inevitably result in rapid improvement and development. Among those working in the field the belief is almost universally held that we are just entering a period when the capabilities, effectiveness, and reliability of guided missiles will increase by orders of magnitude, and their extraordinary military potential will approach full realization.

Structures—Theory, Materials, Methods (*Continued from page 107*)

Efforts to produce curved tempered glass and to improve the properties of acrylics have provided canopies and windows capable of withstanding high-speed, high-altitude flight.

Laminated cellulose products and foamed plastics, such as Lockfoam, have been successfully used for strong, light cores for the sandwich construction of antenna housings. Resin-impregnated Fiberglas sheets for the surface layers of these sandwiches have been highly successful.

Future Material Possibilities

Ingenuity in development and adaptation of many types of materials has furnished to the structural designer a wealth of substance and a range of opportunity beyond all expectations of the pioneer engineer. No single discussion of this type can touch on all of them. The field of future progress is wide open.

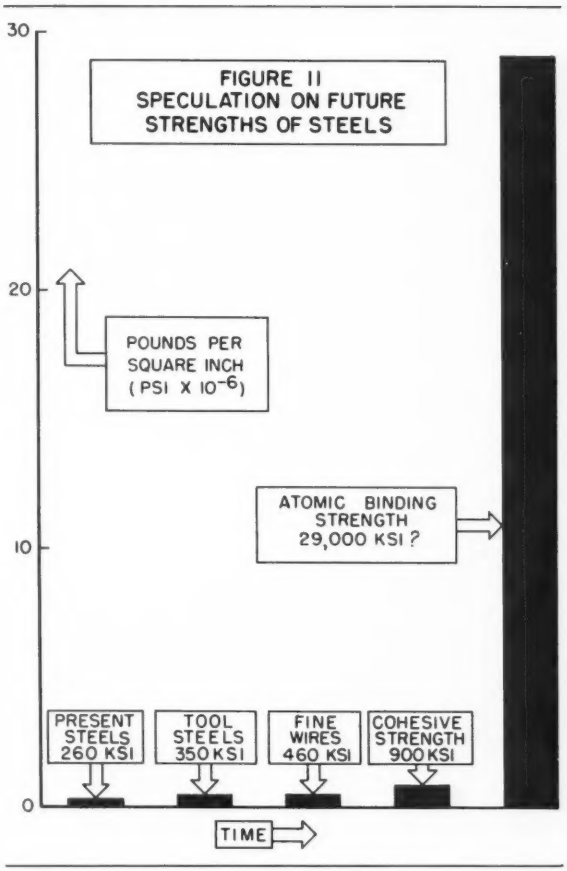
Important developments now under way will lead ultimately to exploitation of still others. Ceramics is one example.

Fine wires have been drawn with strength in excess of 400,000 lbs. per sq.in., and in the laboratory sintered carbides have developed more than 500,000 lbs. per sq.in. compression in the presence of high hydrostatic pressures.

Nuclear physics teaches that materials as we know them consist mostly of empty space, while the nucleus itself is packed with mass at a rate of about 2,000,000,000 tons per cu.in. This would indicate that, when the secrets of atomic binding are better understood, materials may possess strength so infinitely greater than anything known today that they almost defy reason.

From what is now known and from what certain trends indicate, it may some day be possible for man to build an airplane of the Constellation type that would weigh only 400 lbs.

Fig. 11 gives an indication of how far designers may be able to go by further exploitation of materials and methods of construction now under development. The improvements will be profound.



The aircraft designer has powerful tools available to secure efficient, safe, and practical structures for the new high-speed aircraft coming over the horizon. These structures can indeed keep pace with the expanding knowledge of the science of flight.

A Slipstream View of Aircraft Propulsion, 1903–1953 (*Continued from page 117*)

If both compression ratio and temperature were increased, the thermal cycle may be improved, but, in order to do this, considerably more fuel per pound of air must be burned in order to justify the increased internal losses associated with the higher compression ratio. This must lead to a higher jet velocity if the increased fuel is to be justified, and the higher velocity results in increased momentum losses so that a balancing of the losses soon leads to a new optimum.

The net result of these considerations is that there does not seem to be any marked improvement in fuel consumption of the simple jet engine in sight.

All of the above is taken without regard to engine weight. The engine with low fuel consumption tends to be a heavy engine, but, since the engine weight is a relatively small part of the fuel weight in many applications, the more efficient engine is often justified.

An obvious approach to improvement of the fuel consumption of the gas-turbine engines is to impart momentum to an additional mass of air which does not participate in the heat cycle. In this case the mass of air handled may be selected at will, and the basic power unit may be improved independently as to compression ratio

and temperature without suffering the penalty of reduced momentum efficiency.

As part of this consideration, designs and studies are under way on the by-pass engine, the ducted fan, and various forms of the turbopropeller. I am unable to say what is being done with the shrouded propeller, which is one of the interesting alternates.

All of these devices are being evaluated in terms of the potential fuel saving as offset by increased weight and aerodynamic drag, as well as probable augmented service troubles compared with the pure turbojet.

If the propeller is to be used at airplane speeds above about $M = 0.8$, a new design approach will be required. Up to about this speed it is possible to maintain acceptable propeller efficiency by progressively lowering the rotational component of the tip speed which results in a very high angle of advance for the blade sections. As soon as the tip speed passes a critical limit and the L/D of the airfoils is drastically reduced, the angle of advance becomes an important factor and the efficiency of this kind of propeller drops to a low value. It then becomes profitable to turn the propeller very much faster and operate the propeller supersonically at a favorable angle of advance. Correction of the angle of advance is not enough, of itself, however, and the blades must be made extremely thin if acceptable efficiency is to be realized.

The acceptable aerodynamic efficiency of the supersonic propeller has been fairly well established but a difficult structural problem remains to be worked out before the mechanical integrity of this type of propeller can be assured.

From the standpoint of momentum losses, the ideal propulsion system would be one in which all of the frictional boundary layer surrounding the airplane surfaces would be gathered up and accelerated backward with just enough velocity to balance the induced drag of the airplane wings. This would result in a minimum disturbance to the entire air stream and consequently a minimum waste of kinetic energy. Various schemes have been proposed for drawing portions of the boundary layer into the turbine induction system, but there are many problems such as matching of pressures and volumes, loss of the ram compression, and many others having to do with the necessary ducting and modification of the wing structure. It is too early to say whether this line of investigation is apt to lead to a useful result.

Perhaps there has never been a time during the last 50 years when one would have more difficulty in writing about the future of propulsion than at the present. There does not appear to be any insurmountable obstacle to building turbine-type power plants of any output that may be required within reason. We have already pointed out that one of the major limitations of the turbojet engine is its high fuel requirement and that there does not appear to be any reason to expect a major improvement in this respect. This does not necessarily apply to the turbine-propeller combination, whatever its future may be from other points of view.

Since there does not appear to be a favorable prospect of improving the engine as to fuel consumption, the question arises as to what can be expected of the fuel. Fifty years have seen tremendous strides in the antidetonation and many other desirable properties of fuels, but there has been almost no change in the heat output per pound of fuel. Engineers have looked for a long time at hydrogen and hydrogen-rich compounds as a possible source of improvement. However, hydrogen, even in the liquid state, is bulky and does not offer much for modern aircraft where space may be even more important than weight. It is true that some of the metal hydrides combine the advantages of compactness and high heating value, but it appears likely that cost and other logistic problems will rule them out for anything other than certain specialized applications such as rockets and ram-jets for extremely high speeds.

This leaves for consideration the question of nuclear fuels. At first glance the atomic furnace appears to offer a compact device with an extremely high potential output and negligible fuel consumption. There are some difficult engineering problems in connection with the design of the furnace and in tying it in to some form of propulsive engine. These problems do not seem insuperable given time and a sufficient effort. The big obstacle as far as piloted aircraft are concerned is the presence of the intense and powerful array of radiations and the problem of adequately shielding the crew from their harmful effects. There does not appear to be any present knowledge, either theoretical or practical, which would justify too much hope for an attractive solution for broad scale application. What may be done in the future with expendable pilotless aircraft will probably depend on what happens to the costs and logistics of the nuclear fuel. It seems just possible that these two items may be subject to drastic changes in the distant future.

If one is justified in looking into the future at all, it appears most likely that the next 10 years will be occupied to a large degree in the perfection and application of the turbine-type engine, at least as far as the piloted aircraft are concerned. In the field of transport an interesting and perhaps a fruitful competition between the turbojet and the turbine-propeller types should develop. Perhaps some other form of mass augmentation may come into use besides the propeller. One would expect that at least 10 years would elapse before the piston engine is displaced as far as actual use on the air lines is concerned.

It appears probable that turbine engines of either jet or propeller variety can be designed for whatever power output requirement may develop.

Instruments and Control of Flight (*Continued from page 123*)

The face of the instrument is unencumbered with any markings except a central dot or zero. A vertical and a horizontal pointer cross the face as in an ILS cross-pointer meter. The pilot merely manipulates the controls to keep both pointers centered. If the task is a approach, the compass heading, the position with respect to the localizer path, the angle of bank, the angle of glide, and the position with respect to the glide path will all be put into the Zero Reader computer. It properly weighs each piece of information, puts the necessary limits on attitude angles, computes single answers, and displays the answers as deflections of the cross pointers which direct the pilot as to how to move the controls. The pointers respond without any time lag to the pilot's corrective actions. This greatly facilitates his ability to keep them centered.

The basic contribution of this instrument lies in the fact that it eliminates the most confusing step in instrument flying—that is, the pilot's having to figure out from the indications what he ought to do next. Instead of collecting and interpreting the various pieces of information and then deciding what control action to take, he may take immediate control action by centering the director indication without any intermediate mental step.

This director type of instrument will take a permanent position on the flight panel for the primary function of instrument approach.

With the approach path now made smooth and accurate by means of either director type instruments or automatic approach equipment, the remaining problem is to give the pilot reliable, up-to-the-minute visibility information. He must be assured of just when he will be able to see the runway so as to make a visual contact landing. Actual flight studies of this meteorological problem are now being made, and much is being learned which may bring a practical solution to this last and hardest of the instrument-flight problems.

But the airplane itself is showing no signs, even yet, of leveling off in its accomplishments.

As turbojet airplanes continue to step up performance, the effect on the instrument board might be expected to be serious. Such is not the case. The effect is surprisingly small. The ranges on the dials of the altimeters and air-speed meters are increased, a Mach meter must be added, and the gyro horizon must be less affected by accelerations. But the engine instruments are even simpler and fewer in number.

So, after these 50 years, the worst may be over; the second 50 years of flight may well see the pilot's cockpit simpler, more orderly, and perhaps even standardized. He no longer needs more information, he only needs the information now available served up to him in ever better form, more easily digestible. This job will keep the instrument engineers busy for a long time to come.

IAS Library Facilities

To serve Institute members and others in the aeronautical industry, the Institute of the Aeronautical Sciences offers the facilities of:

The W. A. M. Burden Library
2 East 64th Street
New York 21, N.Y.

The facilities of this library are available for reference study at the Institute.

The Paul Kollsman Lending Library
2 East 64th Street
New York 21, N.Y.

This library loans books without charge to members and others in the United States over eighteen years of age. Full information will be sent on request.

The Pacific Aeronautical Library
7660 Beverly Boulevard
Los Angeles 36, Calif.

This is a service and reference library for West Coast organizations. Full information as to its facilities will be sent on request.

The Institute's

Corporate Member Family

Listed below are the principal companies of this country and Canada who have contributed so much to the growth and development of aviation on this side of the Atlantic. Many of them have been directly connected with, or stemmed out of earlier companies engaged in, aeronautics since the inception of powered flight. Others are more recent entries into the rapidly expanding field of the aeronautical sciences.

Old or new, they constitute the foundation upon which our aviation industry is built today. No history of aeronautics or forecast of its future would be complete without a consideration of their individual contributions to it.

The following pages contain necessarily brief, but interesting, stories of the role each company has played, and is playing today, in aviation. The numbers indicate the pages on which each story may be found.—Ed.

Academy of Aeronautics, Inc. ... 135
Adams Rite Manufacturing Company ... 135
Aerojet-General Corporation ... 136
Aerolab Development Company ... 136
Aeronca Manufacturing Corporation ... 138
Aeroquip Corporation ... 138
Agawam Aircraft Products, Inc. ... 140
Air Associates, Inc. ... 140
Airborne Accessories Corporation ... 141
Airborne Instruments Laboratory, Inc. ... 141
Aircraft Radio Corporation ... 141
AiResearch Manufacturing Company ... 141
Allis-Chalmers Manufacturing Company ... 142
Allison Division, General Motors Corporation ... 142
Aluminum Company of America ... 145
American Airlines, Inc. ... 145
American Bosch Corporation ... 146
American Helicopter Company, Inc. ... 146
American Phenolic Corporation ... 148
American Steel & Wire Division, United States Steel Corporation ... 148
Anderson, Greenwood & Company ... 150
Arde Associates ... 150
Associated Aviation Underwriters ... 151
Aviation Engineering Division, Avien-Knickerbocker, Inc. ... 151

Baker Steel & Tube Company ... 152
Beech Aircraft Corporation ... 154
Bell Aircraft Corporation ... 154
Bendix Aviation Corporation ... 158
The BG Corporation ... 161
Boeing Airplane Company ... 162
Booz, Allen & Hamilton ... 163
Brandt Manufacturing Company
Breeze Corporations, Inc. ... 163
The Bristol Aeroplane Company of Canada Ltd. ... 163
Brooks & Perkins, Inc. ... 164

Cal-Aero Technical Institute ... 164
California Panel & Veneer Company ... 167
Canadair Limited ... 167
Cessna Aircraft Company ... 167
Chase Aircraft Company, Inc. ... 170
The Chase National Bank of the City of New York ... 170
Ciba Company, Inc. ... 170
The Cleveland Pneumatic Tool Company ... 172
Clifford Manufacturing Company, Division of Standard-Thomson Corporation ... 172
Consolidated Vultee Aircraft Corporation ... 174
Consultants & Designers, Inc.
Continental Motors Corporation ... 176
Cooper Precision Products ... 178
Cornell Aeronautical Laboratory, Inc. ... 178
Curtiss-Wright Corporation ... 178

Doak Aircraft Company, Inc. ... 182
Doelcam Corporation ... 182
Douglas Aircraft Company, Inc. ... 182
The Dow Chemical Company ... 186
Dzus Fastener Company, Inc.

Eastern Air Lines, Inc. ... 186
Eaton Manufacturing Company ... 188
Edo Corporation ... 188
Elastic Stop Nut Corporation of America ... 188
Electrol Incorporated ... 190
Esso Standard Oil Company ... 190
Ethyl Corporation ... 190

Fairchild Camera and Instrument Corporation ... 190
Fairchild Engine and Airplane Corporation ... 193
Federal Telecommunication Laboratories, Inc. ... 196
Firestone Tire & Rubber Company ... 196
Fletcher Aviation Corporation ... 196
Flight Refueling, Inc. ... 198
Flight Safety Foundation, Inc. ... 198

General Electric Company ... 199
G. M. Giannini & Co., Inc. ... 200
Globe Corporation, Aircraft Division ... 200
The B. F. Goodrich Company ... 200
The Goodyear Tire & Rubber Company ... 202
Grumman Aircraft Engineering Corporation ... 202

Harvey Machine Company, Inc. ... 204
Robert Hewitt Associates ... 204

Industrial Sound Control, Inc. ... 204
Insurance Company of North America ... 207
The International Nickel Company, Inc. ... 207

Jack & Heintz, Inc. ... 207
Johns-Manville Sales Corporation ... 212
Corydon M. Johnson Company, Inc. ... 212
Earle M. Jorgensen Company ... 212

The M. W. Kellogg Company
Walter Kidde & Company, Inc. ... 212
Kollsman Instrument Corporation ... 214

Lavelle Aircraft Corporation 214
Lear, Incorporated 214
The Liquidometer Corporation 216
Lockheed Aircraft Corporation 216
Loewy-Hydropress, Inc. 221
Longines-Wittnauer Watch Company, Inc.

Marman Products Company, Inc. 221
Marquardt Aircraft Company 221
The Glenn L. Martin Company 221
McDonnell Aircraft Corporation 222
Meletron Corporation 224
Minneapolis-Honeywell Regulator Company 227

National Credit Office, Inc. 227
North American Aviation, Inc. 228
Northrop Aircraft, Inc. 230

Pan American World Airways, Inc. 230
The Parker Appliance Company 232
Pesco Products Division, Borg-Warner Corporation 234
Phillips Petroleum Company 235
Piasecki Helicopter Corporation 236
Power Generators, Ltd. 236
The Pure Oil Company 236

Radioplane Company 236
J. B. Rea Company, Inc. 238
Republic Aviation Corporation 238
E. V. Roberts and Associates
A. V. Roe Canada Limited 240
John A. Roebling's Sons Corporation 240
Rohr Aircraft Corporation 240
Paul Rosenberg Associates 242

Schrillo Aero Tool Engineering Company 244
Seaboard & Western Airlines, Inc. 244
Shell Oil Company 244
Simmonds Aerocessories, Inc. 244
Socony-Vacuum Oil Company, Inc. 247
Solar Aircraft Company 248
Sperry Gyroscope Company, Division of The Sperry Corporation 250
Standard Oil Company of California 250
Standard Oil Company (Indiana) 252
The Steel Products Engineering Company 252
Stroukoff Aircraft Corporation 254
Sturgess, Inc. 254
Summers Gyroscope Company 256

Telecomputing Corporation 256
The H. I. Thompson Fiber Glass Company 256
Thompson Products, Inc. 256
Tinnerman Products, Inc. 258
Toolko Engineering Company
Trans World Airlines, Inc. 258
Turbo Products, Inc.

Union Carbide and Carbon Corporation 260
United Air Lines, Inc. 260
United Aircraft Corporation 260
United States Aviation Underwriters, Inc. 262

Vard, Inc.
Vickers Incorporated 264

Western Gear Works 264
Westinghouse Electric Corporation 264
Weston Electrical Instrument Corporation
Wyman-Gordon Company 266

Young Radiator Company 266

ACADEMY OF AERONAUTICS, Inc.

Flushing, N.Y.

In 1932, C. S. (Casey) Jones, George Vaughn, Lee Warrender, and Richard Whatham established The Casey Jones School of Aeronautics at Newark, believing that there was a need for an institution devoted exclusively to training technicians for the aircraft industry. Newark was selected because at that time Newark Airport was the Metropolitan Airport for New York. Two courses were offered, one a 2-year A & E course for aircraft technicians and a $2^1/_2$-year course of aeronautical engineering. The school was certified by the Civil Aeronautics Authority, the first school to receive a rating. When LaGuardia Field was completed, arrangements were made with the City of New York for the construction of a school at the airport known as the Academy of Aeronautics, which started operation in 1939.

In 1938, when it was obvious that war was in the offing, contracts were entered into with the Air Force for the training of technicians. During the war years the entire facilities of both institutions were devoted exclusively to the training of Air Force and Government personnel, and at one time the enrollment exceeded 3,500 and more than 17,000 were trained. At the end of World War II the school returned to civilian status for high-school graduates and veterans, and during its 21 years of operation, in addition to the personnel trained for the Government, more than 5,000 were graduated from the regular commercial courses. In addition, two training plants for instruction of employees of Republic Aircraft are operated at Farmingdale and Port Washington, and to date more than 7,000 employees have been processed.

ADAMS RITE MANUFACTURING COMPANY

Glendale, Calif.

Adams Rite Manufacturing Company, established 53 years as a manufacturer of highest quality locks and hardware, entered the aircraft business as "Rite Hardware Manufacturing Company" in 1936 to supply the first locks and door hardware designed especially for aircraft and made to aircraft standards.

Beginning with commercial and military aircraft such as Douglas DC-2 and B-18, Lockheed Electra, Boeing 314 and B-15, for which all door hardware was supplied, the Company continued through World War II as practically the sole source of this hardware for 90 per cent of all American-built aircraft. The Company now has over 800 proprietory designs of locks, latches, catches, and handles, also sanitary valves and drains, which it regularly supplies to all air-frame manufacturers in this country and Canada and to military depots, air lines, and other operators throughout the world. The Company also manufactures seat and cargo tie-down devices including its patented "Wedjit" fasteners (licensed to United Carr Fastener Corporation) and the approved AMC 2,000–5,000-lb. Tie-down Fittings and Rings.

In 1949, Adams Rite expanded into the field of aircraft controls for which it has complete design and production responsibility for several current fighter, trainer, and transport aircraft. These include Engine Control Quadrants, Grips, Fire Control Switches, Landing-Gear Boxes, and Steering Wheels.

AEROJET-GENERAL CORPORATION

Azusa, Calif.

Pioneer in the rocket field, Aerojet-General Corporation is today the largest developer and manufacturer of rockets and rocket propellants in the United States. The company was founded in 1942 by Dr. Theodore von Kármán, internationally famous aerodynamicist, presently Chairman of the Scientific Advisory Board of the U.S. Air Force, and Chairman of the Advisory Group for Aeronautical Research and Development, NATO. At the present time, Aerojet-General is an almost wholly owned subsidiary of The General Tire & Rubber Company, Akron, Ohio, which entered the Aerojet organization in June, 1944, on a management participation basis and acquired its initial stock holdings in Aerojet in January, 1945. The original Aerojet Engineering Corporation acquired a new corporate title, Aerojet-General Corporation, on April 1, 1953, as the result of its merger into Crosley Motors, Inc., Cincinnati, Ohio, another General Tire subsidiary.

While Aerojet-General has had an important part in the development of many of the outstanding rockets and guided missiles in use today, including liquid-assisted take-off rockets for our most advanced fighters and bombers, forward-firing ordnance rockets, the Aerobee upper atmosphere sounding rocket, and underwater rocket propulsion motors, the company's best known product is its solid propellant JATO (jet-assisted take-off) rocket. Each JATO is a self-contained engine in itself—a cylinder full of propellant which includes oxygen in the mixture so it can burn without air. It has an electrically controlled spark plug that ignites the propellant. The gases resulting from the burning propellant are expelled at an extremely high rate of speed through a venturi-type nozzle, thus developing the thrust that lifts the plane from the ground.

Aerojet's JATO has a long history of spectacular achievement. First developed in 1937 by Dr. von Kármán and a small group of his assistants at the California Institute of Technology, JATO was given its first big impetus at the outbreak of World War II in 1939, when Gen. H. H. Arnold, Chief of the Army Air Forces, requested Dr. von Kármán to explore the possibility of commercial production of JATO.

The amazing success of JATO is a matter of record. The 14AS-1000 (14 sec. duration, 1,000 lbs. thrust) JATO played a heroic role in land-sea rescue during World War II, particularly in the Pacific theaters of war. In recognition of this accomplishment, the company was awarded the Navy's Certificate of Achievement for "the development, construction and production of JATO units which were successfully used in the rescue of thousands of wounded and disabled military personnel in combat areas."

Among the more spectacular applications of JATO was its use in the establishment of the world's record nonstop flight of 11,236 miles from Perth, Australia, to Columbus, Ohio, by the Navy's "Truculent Turtle," land-based Lockheed Neptune P2V patrol bomber; the rescue of twelve castaway American fliers from a 7,700-ft. Greenland ice cap in December, 1948, by a C-47 equipped with JATO; the rescue of six members of the Byrd Expedition at the South Pole on April 12, 1947; and the 40 launchings of a heavily loaded photographic DC-3 off the deck of the carrier "Philippine Sea" during the same expedition for photographic reconnaissance near and over the South Pole.

A number of the commercial air lines, including American Airlines, Braniff International Airways, Ethiopian Air Lines, and Pan American-Grace Airways, have used JATO to lift heavily laden planes off short runways and as an added safety factor in case of engine failure in high altitude airstrips. Aerojet's JATO, which was certified by the Civil Aeronautics Administration for use on commercial air lines in September, 1946, is the only rocket so approved.

The original JATO, which reached a maximum monthly production of 10,000 during the final months of World War II, utilizes a mixture of potassium perchlorate, asphalt, and oil. This material, although it has the advantage of low cost and relative ease of manufacture, results in a smoke exhaust that imposes definite limitations on its military application.

In an effort to improve upon this smoky JATO, Aerojet in 1947 initiated a program under contract from the Bureau of Aeronautics to develop a smokeless JATO of lighter weight and wider operating temperature. Six years of extensive development have brought forth such a smokeless JATO. For the production of this smokeless JATO, Aerojet has constructed an $8,000,000, 8,300-acre plant 16 miles northeast of Sacramento, with an ultimate monthly capacity of 30,000 such JATOs.

Recognition of Aerojet's achievement in developing this smokeless JATO is the following tribute from Rear Adm. Thomas S. Combs, former Chief of the Bureau of Aeronautics, U.S. Navy: "The successful completion of the development of the new smokeless JATO (15KS-1000) by the Aerojet-General Corporation is an outstanding contribution to the defense of this nation. It marks the culmination of 6 years of concentrated effort by many individuals of your organization. Please accept my personal congratulations on a job 'Well Done' and extend to each of your associates my deep appreciation.

"It is particularly noteworthy that the specifications for the new JATO have been fully met and for the first time the Air Force and Navy have available for their use a thoroughly reliable, all-weather, smokeless JATO. Few development programs are so conspicuously marked with success as this one."

AEROLAB DEVELOPMENT COMPANY

Pasadena, Calif.

Aerolab Development Company, Inc., was established in 1945 as the single western source for wind-tunnel models. Augmenting this service and commensurate with the skill and precision necessary in model building, the Aerolab manufacturing facility was made available to local industry for the construction of research and developmental equipment. The quality and service offered soon earned national recognition of Aerolab as a dependable source for experimental work, and an engineering department was established to design, as well as build, the specialized equipment associated with aircraft and missile testing. Wind-tunnel models, internal and external balances, and mechanical and test equipment are among the design specialities of this group.

A small subsonic wind tunnel of 250 m.p.h. and 10 sq.ft. test-section area was developed as a proprietary product and gained immediate acceptance. Over a dozen of these have been sold to universities and industrial organizations (two to Douglas Aircraft, for example). A supersonic tunnel for classroom demonstration, instruments, manometers, rakes, etc., are among the standard products manufactured.

Probably the outstanding specialized service offered by Aerolab is the design, as well as fabrication, of free-flight dynamically similar models of aircraft and missiles for telemetering supersonic flight data. Aerolab has built more of these models than all other commercial sources combined.

Since Aerolab is a service organization, it is difficult to define "contribu-

Typical supersonic free-flight research model of the Aerolab Development Company.

Designers and manufacturers of
dependable airborne electronic
equipment since 1928
Aircraft Radio Corp.
Boonton, New Jersey
ARC

tions" to aviation. Perhaps our development of an economical gyro-stabilized autopilot system for expendable free-flight models will qualify, this being a major step toward reducing costs of this type of testing.

AERONCA MANUFACTURING CORPORATION

Middletown, Ohio

Aeronca Manufacturing Corporation, this year marking its 25th anniversary, shares half of aviation's 50 years of history and progress. World's first light-plane manufacturer, it began as the Aeronautical Corporation of America at Lunken Airport, Cincinnati, where it was founded in 1928 by a group of Cincinnati businessmen.

In light-plane boom years from 1928 to 1949, the company produced such popular models as the Roche-designed C-1, C-2, C-3, stepped-up horsepower in later models like the Champion, Chief, Super Chief. As private flying swept overseas, Aeronca expanded with the Aeronautical Corporation of Great Britain, Ltd., and the Aviation Equipment & Export Company (AVIQUIPO) with branches in South America—and even in Hong Kong.

With the need of a less congested location in 1940, the plant moved to the municipal airport site at Middletown and changed its name to the Aeronca Aircraft Corp. Reaching a light-plane production high during World War II, it built sturdy tandem trainers and the famous "grasshopper" planes important for scouting, liaison, and messenger service. War production also included gliders, cargo, and ambulance craft for the Air Corps; recognition was accorded employees with the coveted Army-Navy award for excellent production.

Reverting to light-plane output after the war, Aeronca was first to install a continuous production line and rolled off 58 planes per day to keep pace with the light-plane demand of people interested in private flying.

In 1949, when the demand suddenly ceased, all light-plane companies took a simultaneous nosedive and many closed permanently.

Aeronca feebly survived. When it hit its all-time low with no money to buy materials or pay loyal employees who worked weeks without wages, an industrial miracle happened. The story was labeled variously by newspapers as "the business romance of 1949" and "the Cinderella story of industry."

Its reorganization resulted from a generous community gesture—typical of the civic-spirited, close-knit Ohio town where it had located 9 years before. Leading industrialists and businessmen of Middletown got together and within an hour raised $200,000 in subscriptions, which were paired with a similar amount from the Reconstruction Finance Corportation (RFC). Then stockholders approved issuance of approved stock. Finest phase, illustrative of Aeronca's splendid employee-management relations, was the company's Independent Union member's vote to turn back a portion of their wages for common stock.

Contracts began to flow in. And the one-time airplane manufacturer started producing everything from chicken feeders to the 3.5 bazooka of Korean fame. Then Aeronca, known for its precision assemblies, came into its own as a subcontractor for major air-frame components—an impressive list that included jet and bomber assemblies, power-plant assemblies, guided-missile components.

It has reached its quarter-century mark with better than a $30,000,000 backlog, and past year's sales above $12,000,000. Over 1,700 employees in its two Middletown plants make it the town's second largest employer, while a plant recently leased at nearby Miamisburg will give it operational elbow-room and increase employment and production.

John A. Lawler, Aeronca's president who saw the company through its reverses, has rebuilt his company on a sound foundation and with the complete confidence of his employees and the community.

AEROQUIP CORPORATION

Jackson, Mich.

Look high in the sky where planes outdistance sound and the siren voice of adventure calls. The jets, the transports, the troop carriers, and even the small private planes have a vital thing in common. What? Fluid carrying lines. . .and wherever you find fluid carrying lines on an airplane today, you are sure to find Aeroquip flexible hose lines.

The development of Aeroquip flexible hose lines with detachable reusable fittings represented an entirely new idea in the field of flexible plumbing. Conventional hose lines with swaged-on fittings had been used by the aircraft industry for years. Such fittings could not be removed from a damaged hose and attached to a new piece of hose. The user had to order hose lines ready made in the required length for every installation. This meant large inventories of hose lines in many sizes and lengths. With Aeroquip hose and fittings, inventories can be hand-assembled on the spot, using bulk hose and fittings.

The founding of a company to develop this radical departure in flexible hose lines was the inspiration of Peter F. Hurst. It was Hurst who first saw the need in the aircraft industry for an improved hose line that would ensure maximum performance under the most adverse operating conditions. He also had an idea for a self-sealing coupling that allowed the interchanging of hydraulic accessories without draining or priming the system. Aeroquip Corporation was founded in Jackson, Mich., on April 26, 1940.

Early in World War II when planes were being ferried from Alaska to Siberia, it was discovered that many were having difficulty operating because of hose-line malfunctions; others had no difficulty at all. These were Aeroquip'd. As a result, because of lightness, savings of rubber, ease of installation, inventory control, and flexibility at low temperatures, Aeroquip became standard on all military combat aircraft.

By 1945 Aeroquip's sales had mushroomed to over $6,000,000, but at the war's end contracts were terminated and sales dropped to a new low. It was then that Peter Hurst recommended reorganization and expansion into industrial markets. Industrial counterparts of Aeroquip hose, fittings, and self-sealing couplings were introduced. Today, Aeroquip products, in addition to the important aircraft market, are standard equipment in twelve capital goods industries, and sales for 1953 will exceed the $20,000,000 mark.

However, Aeroquip is still not content to rest on its laurels but is constantly designing and developing new products with which to serve the aircraft industry. This growing list includes:

The Slide-Seal Coupling, a low-cost, compact, lightweight coupling for quick disconnection and connection of fluid carrying lines.

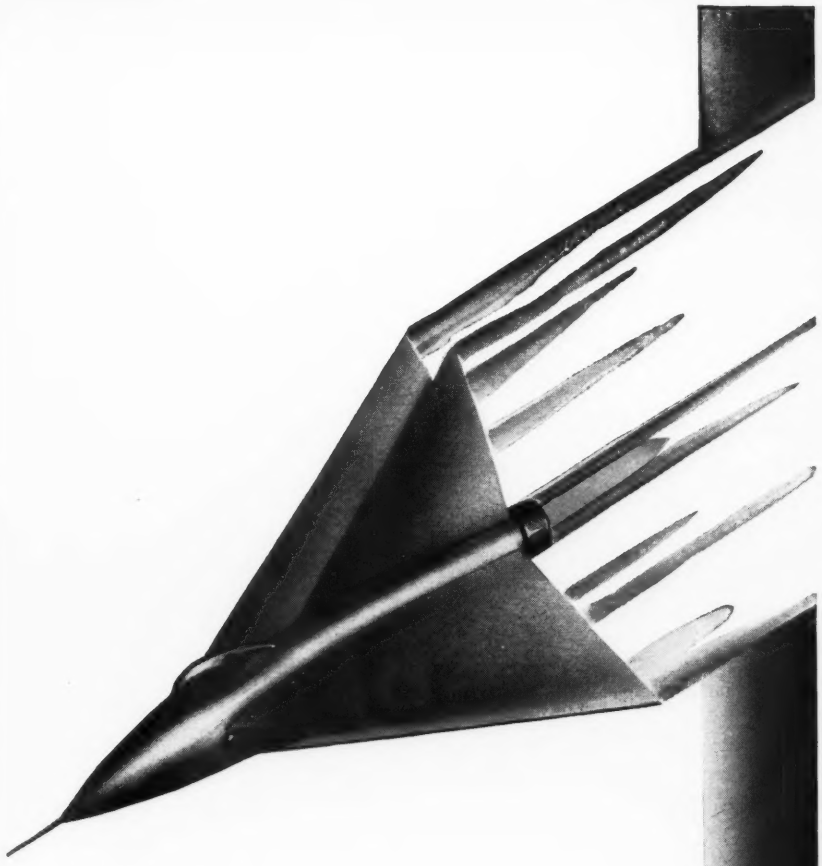
The Flex Joint, first connector to allow successful flexing of rigid fuel lines.

"Little Gem" Fittings, a radical development in detachable, reusable fittings.

Anti-Icing Hose Lines, first to convey hot air up to 500°F. plus.

Coverless Engine Hose, a new hose for aircraft engine plumbing. Lighter in weight, more flexible, and less costly.

Today, 13 short years after its founding, Aeroquip is recognized as the world's leading producer of flexible hose lines and couplings for aircraft and industrial applications. The spirit that best typifies the drive to the number one position can be summed up in the words of its President, Peter Hurst, at a recent sales conference. "There can be no doubt you've done a good job, but you will have to do even better. We can't stand still. We must go forward or we will surely go backward."



This wall has more substance to it!

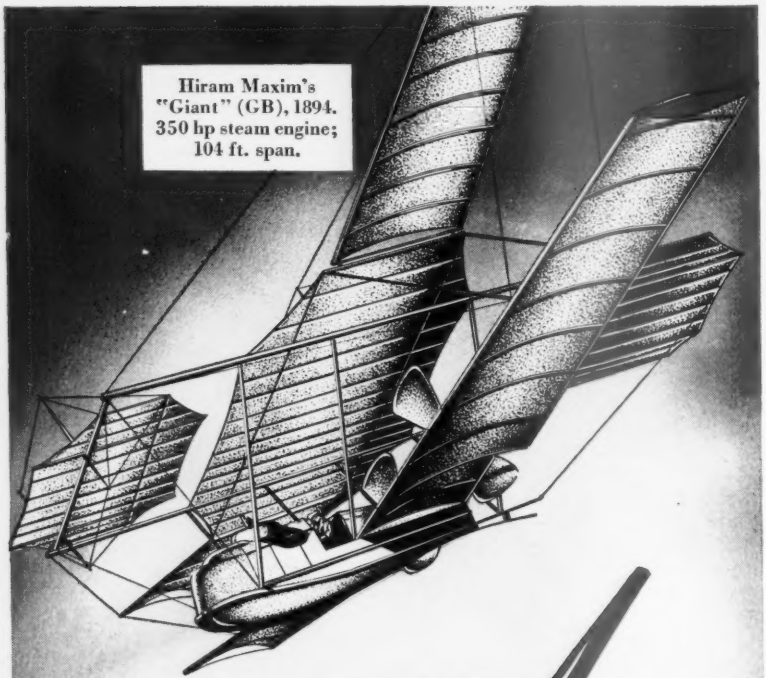
The Sonic Barrier was tough enough!

But penetrating the wall of high temperatures that lies ahead requires development of many new components.

We specialize in development and manufacture of aircraft and engine components made of high temperature alloys.

Perhaps we can aid you in your progress toward high mach number performance.

SMITH-MORRIS CORP.
PRECISION AIRCRAFT COMPONENTS
FERNDALE 20, MICHIGAN



...out of this came Aviation

An industry whose tremendous growth has forced the continued expansion of the manufacturing facilities of many companies to feed this great industry's carnivorous appetite for production.

Indiana Gear Works is such a company—we began to produce precision parts for the aviation industry in 1933.

Today, twenty years later, we find ourselves continuing to increase our physical plant in order to gain the production capacity we need to consistently produce quality precision parts and assemblies.

The manufacturing facilities of IGW at Indianapolis

INDIANA GEAR

INDIANA GEAR WORKS, INC. • INDIANAPOLIS 7, INDIANA

AGAWAM AIRCRAFT PRODUCTS, INC.

Sag Harbor, L.I., N.Y.

Agawam Aircraft Products, Inc., was organized in December, 1940, by Albert P. Loening for the purpose of making precision parts for the aircraft industry.

From the beginning, the major output has been taken by the Grumman Aircraft Engineering Corporation, and during World War II Agawam manufactured many parts for Grumman Hellcats and Avengers. For this work it was awarded the Army-Navy "E" five times—an exceptional record for a small aircraft parts plant.

Besides precision parts, the Company now produces hydraulic assemblies, and its entire output still goes to the Grumman company.

AIR ASSOCIATES, INC.

Teterboro, N.J.

Air Associates, Inc., was founded in 1927 to serve the diversified needs of the then undeveloped aviation industry.

Operations were begun in a small Fifth Avenue store in New York City, which soon became a sort of "clearing house" for aviation. Through here were funneled the many requests of the air-minded public for information, as well as the problems of other members of the industry. The new organization soon found itself performing a many-sided job for the industry . . . a job that ranged from selling tickets for the Graf Zeppelin to building hangars, performing engineering services, and acting as a distributor for a host of aircraft products.

As the aviation industry grew, so did Air Associates. The company moved to larger quarters on the edge of Roosevelt Field, Long Island, then the center of aviation activity in the East. To meet the increased demand for new and better products, AA designed and began manufacturing gear boxes and seat belts—the beginning of what was to be the Aircraft Products Division in Teterboro. Also at Roosevelt Field was offered a complete maintenance, repair, overhaul, and distribution service to the industry.

In quick succession, branches were established across the country to offer a nation-wide service. First, the Chicago Branch was founded in 1930, Glendale in 1934, and Dallas in 1936.

With a firmer foundation for the industry set by the Civil Aeronautics Act and with the increasing demand for aviation components and supplies, Air Associates built the present 116,000-sq.-ft. Teterboro plant in 1940 in which it expanded its engineering and production facilities.

The company's initial venture in the field of electronics was the development and production of aircraft interphone sets. By 1941, it was also producing various types of receivers and transmitters for light aircraft and police patrol vehicles. During World War II a staff of 400 trained electronics personnel produced thousands of transmitters and receivers for military use. Air Associates' electronic facilities and personnel were moved to a larger (65,000 sq.ft.) building in Orange, N.J., in 1951.

Today, Air Associates, Inc., consists of six divisions—the Aircraft Products Division, Teterboro, N.J.; the Electronic Equipment Division, Orange, N.J.; and the Aviation Supplies Divisions at Hackensack, N.J., Chicago, Ill., Glendale, Calif., and Dallas, Tex. In addition, two branches are located in the Southeast—one at Atlanta, Ga., and the other at Miami, Fla.

The growth of Air Associates, like that of the aviation industry, is an amazing story of faith, initiative, and determination—and Air Associates' future in this horizonless, yet still embryonic, industry is as unlimited as the industry itself.

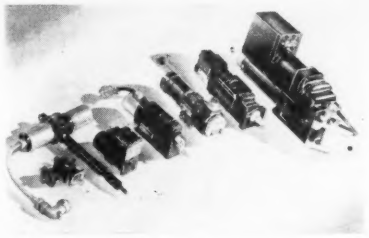
AIRBORNE ACCESSORIES CORPORATION

Hillside, N.J.

Airborne Accessories Corporation was organized in 1947 to produce electric actuators for aircraft. The first product was the "Trim Trol," 26-volt rotary actuator, for trim-tab operation. The "Rotorac," a multiple revolution rotary actuator, was developed to drive tab-operating jackscrews, and from this the "T" type "Lineator," with integral jackscrew, was developed. Later, the "Baby Trim Trol" was designed to mount in the leading edge of thin control surfaces yet be capable of 600 lb. in. torque and weigh only $2^1/_4$ lbs. The success of these early models established Airborne's reputation in the aircraft manufacturing field.

The stepped-up aircraft activity, due to the war in Korea, resulted in a gradual increase in the size of actuators developed to meet specific requirements, and three more basic motor sizes were put into production, all 26-volt direct-current models. Actuators are now produced with motors having power ratings from 0.004 to 1.25 hp., all with brakes and some with clutch and brake.

Actuators range in size from the "Rotorette" with load sensitive limit switches and weighing under $1^1/_2$ lbs. to a "Lineator" rated at 10,000 lbs. thrust and weighing about 23 lbs. The "Rotorette" is used for valve operation and the large "Lineator" for stabilizer positioning and, experimentally, for operating a "flying tail" on a supersonic fighter.



Some products of the Airborne Accessories Corporation.

The policy at Airborne has been to develop a standardized line of actuators which, with only slight modifications, can meet most aircraft requirements within the range covered. In addition to actuators, Airborne produces a geared brake, which is used to hold a set position such as a control bungee, and a line of "ANGLgears," right-angle two- and three-way gear boxes. Current development projects cover actuators with 400-cycle, 110-volt motors and various control systems.

AIRBORNE INSTRUMENTS LABORATORY, INC.

Mineola, N.Y.

Airborne Instruments Laboratory, Inc., has become one of the major electronics research and development laboratories studying problems of air navigation and development of electronic equipment for the aviation industry.

AIL was created during World War II as part of the Office of Scientific Research and Development under the sponsorship of Columbia University. Its first assignment was the development of air-borne submarine detecting devices. This resulted in the MAD (Magnetic Airborne Detector), now also used for geophysical exploration in the search for oil-bearing formations.

AIL distinguished itself with its contribution to Traffic Control during the Berlin air lift. Members of the Staff helped to develop radar navigation systems for airways traffic control, permitting the high volume of traffic to be handled. Among its more recent accomplishments receiving international recognition is Airport Surface Detection Equipment (TAXI RADAR). This device presents a photographic-like animated reproduction of an air terminal permitting tower controllers to effectively deal with ground traffic problems in times of poor visibility.

The Laboratory was incorporated as a private enterprise at the close of World War II, with technical personnel from Radiation Laboratory at M.I.T. and Radio Research Laboratory at Harvard joining the new enterprise. Although almost every type of applied electronic research has been included within the scope of the Laboratory's work, its major activity has been on military projects. The Laboratory now produces a limited number of high-precision instruments for the commercial market and is still expanding its manufacturing activities, as well as broadening its research program.

AIRCRAFT RADIO CORPORATION

Boonton, N.J.

Aircraft Radio Corporation started active development work in 1927. Engineering studies were first focused upon the local radio interference produced by aircraft power plants and upon radio wave-propagation phenomena between air and ground. The company operated its own aircraft and maintained unusually close association between radio engineering and field operations. It constructed and still maintains what is probably the first domestic airport established solely for the purposes of radio experimentation.

The company's earliest products included an electric-wave altimeter, electrical spark-plug shields for radial engines, radio mast antennas, and the first radio navigational receiver regularly used in the contract mail service by Pitcairn Aviation, National Air Transport, and others. For air-to-air communication the company initiated the design of small disposable radio units having remote controls, together with horizontal built-on antennas, which combined to provide practicable communication service between single-seat aircraft. Radio command sets developed by the company were standardized by the U.S. Navy and the Army Air Corps, and were manufactured in various forms by the company until after World War II.

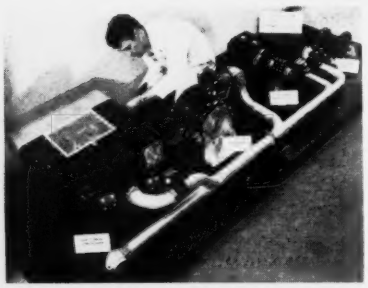
The company is presently active in the general field of air-borne electronics for both civil and military applications.

AIRESEARCH MANUFACTURING COMPANY

Los Angeles, Calif.

Flight at higher speeds and higher altitudes has been the purpose of products produced by AiResearch Manufacturing Company, Division of The Garrett Corporation, since its conception in 1939.

Starting with aviation's first tubular heat exchangers and the first oil coolers, the Los Angeles firm now produces close to 1,000 different aircraft components at its Los Angeles and Phoenix plants.



First complete auxiliary pneumatic power system for aircraft was produced by AiResearch Manufacturing Company. Shown above is the system that includes the gas-turbine compressor, air-turbine motor, refrigeration unit, and air-turbine starter.

The Boeing B-17 Flying Fortress carried two of AiResearch's initial contributions to the aviation industry. They were the automatic oil temperature controls and the first mass-produced all-aluminum intercooler. Other vital heat-transfer unit developments by AiResearch were a thermostatically controlled shutter, temperature surge protection, a standard four-part valve, a flat-tube intercooler, an oil cooler elliptical in shape, and a dip-brazed aluminum oil cooler.

Today, AiResearch produces 75 different kinds of heat-transfer equipment, including complete oil temperature-regulating systems, cabin coolers, after-coolers, air-oil coolers, exhaust heat exchangers, heat exchangers for AiResearch turbine refrigeration systems, as well as the oil-to-fuel-type coolers, another AiResearch first.

Aviation's first completed self-powered cabin pressure regulator manufactured by AiResearch was used on the Boeing B-29 in 1942 and was the prototype of AiResearch regulators used on military and commercial planes of today.

More than 15,000 such Boeing-licensed systems were produced for the big bombers of World War II. Now AiResearch produces 60 varied cabin pressure control types. Latest commercial planes to use the AiResearch air-conditioning equipment are the Lockheed Super Constellation, Douglas DC-7, Martin 404, and Convair 340, as well as private executive transports. An entire system consists of cooling, heating, and pressurizing units, as well as temperature and pressurization controls, safety valves, and dump valves.

Another contribution by AiResearch was the first air expansion cooling turbine to fly, and it was used on the Lockheed P-80 in 1944. The first air cycle refrigeration system for commercial aircraft was also designed and manufactured by AiResearch. Currently, AiResearch manufactures nine basic types of air turbines ranging in airflow from 7 to 115 lbs. per min.

The first practical, packaged application of the Hilch tube principle applied to refrigeration systems has been made by AiResearch.

In 1941, as an adjunct to heat-transfer units, AiResearch entered into electrical power equipment. The first complete line of small, intermediate duty actuators was designed for, and accepted by, the Air Force the same year. Also at this time AiResearch started to produce electronic products.

AiResearch now makes 250 a.c. and d.c. motor-driven actuators as well as a.c. motors from 0.004 to 3 hp. and d.c. from 0.0005 to 15 hp. All a.c. motors employ a magnetic-type brake of AiResearch design which requires no additional coils or wires.

AiResearch, largest component manufacturer in the business, was also first: to adapt turbine equipment to ground heater units; to apply air cycle refrigeration to ground use; to develop a standardization of heat exchangers and oil coolers, as well as to manufacture initially many varied type air valves for military and commercial aircraft.

In 1947 AiResearch designed and built the world's smallest gas-turbine compressor, capable of producing 100 hp., and it was to become the heart of the first low-pressure auxiliary pneumatic power system. Other components of the AiResearch system were: the first air-borne self starter for jet and turbojet aircraft which is capable of giving an unlimited number of starts and was initially used on the Convair P-5Y Turbojet Flying Boat; aviation's first air cycle refrigeration unit; an air-turbine motor developed by AiResearch to supply other air-borne accessories with power; and the first completely automatic control system for small gas turbines.

ALLIS-CHALMERS MANUFACTURING COMPANY

Milwaukee, Wis.

Since 1941, the Allis-Chalmers Manufacturing Company has supplied large quantities of equipment to the Air Services. During World War II, the Company built and operated two plants producing over 100,000 turbosuperchargers and approximately 15,000 geared superchargers for the USAAF. A limited number of de Havilland H-1 "Goblin" jet engines were also manufactured at the invitation of the Bureau of Aeronautics.

In 1951, the Company undertook construction of a large plant at Terre Haute, Ind., for production of axial-flow compressors for the J65 "Sapphire" turbojet engine. In 1952, the Company's West Allis Works commenced regular deliveries of Pratt & Whitney Aircraft prototype YT34 turboprop engines for use by the Air Force and Navy. These engines are being shipped completely assembled and ready for ground tests and installation in aircraft.

Allis-Chalmers has furnished a number of large centrifugal- and axial-flow compressors for aeronautical research work by NACA and the Air Force. Rated airflow on some machines is up to 1,000,000 cu.ft. per min., and discharge pressures are as high as 2,500 lbs. per sq.in. gage. Smaller compressors have been furnished to educational institutions for aeronautical engineering classwork and research. Several large dynamometers for engine test cells have been supplied to aircraft-engine manufacturers.

ALLISON DIVISION, GENERAL MOTORS CORPORATION

Indianapolis, Ind.

The stupendous accomplishments of the past 5 decades, in an entirely new field of transportation, could have developed only in a country where man and enterprise were free to experiment, expand, and produce.

Only in America could a privately owned company like Allison Division of General Motors Corporation have set up the test and production facilities that produced such an impressive number of the engines, bearings, and propellers which have helped man to fly ever faster, farther, and more efficiently.

Allison's entry into the world of aviation occurred in 1917 when they built two Liberty twelve-cylinder V engines. These were the first of the thousands of aircraft engines that were to be built by Allison.

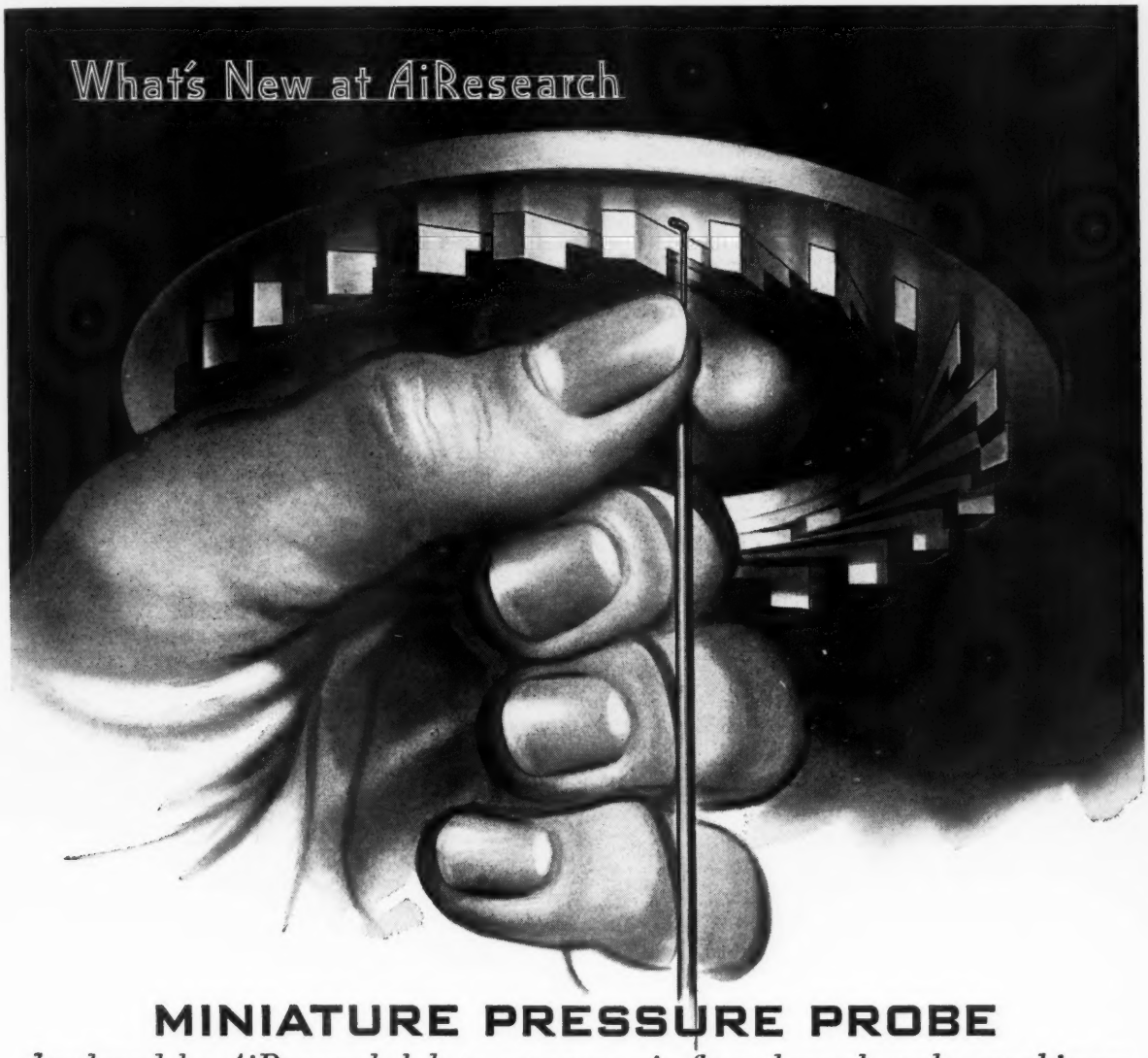
A long-time manufacturer of complex mechanical equipment, Allison today devotes a large part of its strength and resources to the design and production of high-power equipment for the military services.

At the present time, Allison is producing in large quantities two types of turbojets—the J33 centrifugal-flow and the J35 axial flow.

The Allison J33 centrifugal-flow turbojet engine has been used chiefly in the Lockheed F-80 Shooting Star, the first United States production jet fighter. Although this airplane is now nearly 10 years old, it was used extensively in combat in Korea where it proved its ability to withstand battle damage and carry loads of bombs, rockets, and napalm equivalent to the weight of a standard passenger car from each wing.

Also developed from the Shooting Star is a two-seater trainer configuration identified by the Air Force as T-33,

What's New at AiResearch



MINIATURE PRESSURE PROBE

developed by AiResearch lab to measure air flow through turbo-machinery

This tiny total pressure probe — part of a hypodermic needle and a section of 72 thousandths tubing — is a typical AiResearch requirement. It could not be purchased so it was created by an AiResearch laboratory technician.

Inserted into small, high speed turbo-machinery, it is designed to measure true total pressure within yaw variations up to 30° at velocities close to Mach 1.

By use of this total pressure probe, it is possible to make correction of air flow design to further improve the efficiency of small AiResearch air and gas turbines.

This is another example of how AiResearch laboratories must design and develop their own tools and equipment in order to create the unique, highly specialized AiResearch components so vital to every type of modern American aircraft.

Would you like to work with us? Qualified engineers, scientists and skilled craftsmen are needed here.

AiResearch Manufacturing Company

A DIVISION OF THE GARRETT CORPORATION

LOS ANGELES 45, CALIFORNIA • PHOENIX, ARIZONA

DESIGNER AND MANUFACTURER OF AIRCRAFT EQUIPMENT IN THESE MAJOR CATEGORIES

Air Turbine Refrigeration · Heat Transfer Equipment · Electric Actuators · Gas Turbines · Cabin Superchargers · Pneumatic Power Units · Electronic Controls · Cabin Pressure Controls · Temperature Controls

and TV-2 by the Navy. This plane is also powered by the J33 turbojet engine. Virtually every Air Force and Navy jet pilot gets his jet training in this type of aircraft.

Another development of the Lockheed F-80 is the two-place F-94, which carries radar and radar operator for all-weather day or night interception. An afterburner is used with the engine for maximum rate of climb.

The Navy also uses the J33 in the Grumman F9F-3 and F9F-5 Panther and the F9F-7 Cougar. The J33 also has been used to augment reciprocating engines in the North American AJ-1 and the Martin P4M Mercator.

The J33 is the first jet engine built in production quantities in this country, dating back to January, 1945. It has been under constant development at Allison toward higher power and greater dependability. The first engines built in the series started at 3,750 lbs. of thrust and are now up to more than 5,200 lbs.

Allison has designed and furnished thrust augmentation equipment consisting of both water-alcohol injection and afterburning. The engines are currently permitted, by Air Force technical order, 600 hours of operation before overhaul, and where there are facilities for minor repair, 1,200 hours are permitted.

The J33 is the only centrifugal-type jet engine that has operated 1,000 hours; one engine reached this figure at Williams Air Force Base in December, 1951. Tear-down and inspection revealed that the engine was in good condition. It was then reassembled and checked on a test stand against the guaranteed performance required of a new engine, and, despite its 1,000 hours of operation, it met the requirements of a new engine and was returned to service.

The J35 engine has been in production at Allison since 1947. It also has undergone a period of intensive development toward higher thrust and improved dependability. Originally rated at about 4,000 lbs. thrust, current engines of this series now in production produce more than 5,600 lbs. thrust. Its service life also has been prolonged considerably, and it is permitted, by Air Force technical order, 500 hours operation before overhaul and 1,000 hours operation where there are facilities for minor repair. In September, 1951, a J35 engine was operated 1,000 hours at Hamilton Air Force Base and thus became the first 1,000-hour turbojet engine of any type.

The J35 turbojet has been used most extensively in the Republic F-84 Thunderjet. This is the airplane that was used extensively in Korea for most of the fighter-bomber attacks on ground installations. During 1952, the Air Force estimates that the Thunderjet flew more than 150,000 combat hours. The latest version of the Republic F-84 Thunderjet is the first production aircraft equipped with air-to-air refueling. This in-flight refueling has permitted the F-84 Thunderjet to make long overwater flights covering distances that previously had been unattainable by single-engined fighters with either piston or turbine engines.

In two history-making mass flights across the Pacific in 1952, Allison jet engines helped to demonstrate that it is possible to fly single-engined jet fighters over wide expanse of water to reach a combat area quickly.

Another principal use of the J35 engine is in the Northrop F-89 Scorpion, which uses two J35 engines equipped with afterburners. The Scorpion is another two-place, radar-equipped interceptor for all-weather operation, day or night.

Allison also developed, and is now in early production on, the T40 turboprop engine. It was developed under sponsorship of the Navy and has a guaranteed static rating of 5,500 hp. This engine has twin power sections connected by extension shafts to a reduction gear driving contrarotating propellers. Each power section drives both propel-

lers, and for cruise, single-power sections can be declutched for maximum fuel economy.

A single power section also is used with a single rotation reduction gear and propeller for a complete engine with half the horsepower of the T40. This engine is the Allison T38 turboprop.

Today there are only four U.S. aircraft powered with turboprop engines, and all use Allison turboprops.

Every U.S. jet-powered missile that has flown with turbojet engines is powered with Allison engines.

In September, 1952, Aeroproducts Division of General Motors, Dayton, Ohio, was consolidated with Allison Division. This operation manufactures propellers for the Fairchild C-119 Packet and the Douglas AD series of aircraft, including the A2D turboprop. Aeroproducts also makes actuators, which is an electrohydraulic mechanism that acts somewhat like power-steering in the pilot's operation of the control surfaces of his airplane. This consolidation strengthens General Motors' position in the turbine power field.

Every Allison employee shares the pride of the division in our vast contribution to the advancement of powered flight.

ALUMINUM COMPANY OF AMERICA

New Kensington, Pa.

When the Wright brothers' "Flyer" chugged into the air at Kitty Hawk, aluminum contributed to the success of the venture. The cylinder block of the 152-lb. engine was an aluminum-alloy casting.

For a number of years thereafter, the role of aluminum in aircraft continued to be confined primarily to engine parts. Heat-treated aluminum alloys had not yet made their appearance.

Duralumin, the first heat-treatable aluminum alloy, came into the picture a few years before World War I. With this alloy, the aircraft industry and the Aluminum Company of America, working together, learned now to make use of aluminum in aircraft construction. These two industries have solved many problems on a cooperative basis. There have been relatively few revolutionary advances, and it is only by reviewing the long-term results that one can appreciate the tremendous gains that have been made.

Throughout the 50 years that man has been flying, Alcoa has devoted a large percentage of its top metallurgical talent to a thorough and systematic investigation of every conceivable method for improving the strength of aluminum alloys, both wrought and cast. Today, aluminum-alloy castings having nearly two and one-half times the typical tensile strength of the one used by the Wright brothers are commercially available. Even greater progress has been made in the development of high-strength wrought alloys. Alcoa's experimental air-frame structural alloy, XA78S, is about three times as strong as the best available in 1903. Perhaps the biggest single jump in tensile strength came with the introduction of heat-treated duralumin-type alloys from Germany shortly after World War I. Developments since then have continued steadily, even though each successive gain seems more difficult than the preceding one.

The story on product development is similar. Starting in the early days with modest facilities for producing sheets, tubes, extrusions, and other products required by the aircraft industry, Alcoa has steadily developed these facilities in a continual seesawing action. Sometimes the supplier can make a given product bigger, wider, thicker, heavier, or thinner than the aircraft industry requires, and at other times the industry needs dimensions that are beyond the capabilities of the supplier. The new sheet and plate mill at Davenport, Iowa, is a good example of Alcoa's response to the ever expanding requirement of the aircraft industry.

The skilled research staff maintained by Alcoa has always devoted a great deal of attention to all phases of aircraft applications. It has made many important contributions to the processes, as well as the materials used in aircraft construction. Alcoa's careful and extensive testing of mechanical properties, in addition to those required for inspection, has enabled aircraft designers to make full use of aluminum-alloy products with confidence.

AMERICAN AIRLINES, INC.

Flushing, N.Y.

Engineering has been a force in American Airlines dating back to the incorporation in 1930 of the air-line's predecessor company, American Airways, and the thinking and planning of the Engineering Department under Vice-President William Littlewood has had tremendous impact on the entire air-transport industry. The department by itself has developed much equipment now in common use on all air lines, and in cooperation with other operators and manufacturers, it has taken a prominent part in other advances in the industry.

In development of aircraft it has been pre-eminent.

In 1933, it set the specifications for the cabin interior of the Curtiss Condor Sleeper, with which American Airways established the first transcontinental sleeper service.

In 1935, it produced the specifications and sponsored the DC-3.

In 1936–1939, with four other air lines, it sponsored the DC-4E, and with one other air line it sponsored the final DC-4, which became the C-54 of World War II.

In 1945, it produced the specifications for the DC-6, which American sponsored. At the same time it presented an analysis of a postwar replacement for the DC-3. The specifications set forth resulted in the Martin 202 and the Convair 240. American sponsored the Convair.

And in 1951, it produced the analysis of, and specifications for, the DC-7, which American Airlines has sponsored.

Research and development by AA engineers on hundreds of air-line problems have been equally impressive within the industry.

In 1930, American set up the first air-line laboratory for the testing of fuels and lubricants, work that resulted in the formulating of uniform specifications for commercial aircraft fuels and lubricants.

Between 1936 and 1946, American engineers instigated and made the first air-line use of accurate fuel metering determination by fuel/air analyses, fuel flowmeters and engine torquemeters for power determinations and settings.

In 1940, the department developed the flashing navigation lights for transport aircraft. These are now standard on all air liners.

From 1944 through 1948, AA engineers conducted investigations and flight tests to determine the operational uses of air-borne radar. This work, done under contract for the Navy, antedated similar work now being continued in the industry.

In 1938, American was the first to equip its entire fleet with full-feathering propellers, and in 1946, with its DC-6's and Convair 240's, it became the first to use reverse-pitch propellers.

In 1942, the Engineering Department, cooperating with General Electric, did the airplane engineering and flight testing of a B-23 to determine the type of superchargers to be used for pressurization of the B-29 and the C-97. And in 1946, again with its DC-6's and Convairs, American became the first air line to operate a fleet of pressurized passenger planes.

Between 1937 and 1945, the AA Engineering Department engaged in intensive investigation into icing of wings, propellers, air-speed indicator systems, and windshields, work that led to the development of deicing devices for the various components.

AA developed and installed the first windshield wipers in 1938–1939 and followed up in 1941 with the development and first fleetwide installation of birdproof windshields.

In 1944, the Department, after an analysis of Transport Category Regulations, engaged in an industry-wide educational campaign that resulted in substitution of safety climb requirements for the 80-mile-stall-speed requirement for landings. This revision permitted the postwar transports to carry the pay loads for which they were designed, whereas the 80-mile-stall-speed regulation would have limited the pay load and would have necessitated fares proportionately higher.

AMERICAN BOSCH CORPORATION

Springfield, Mass.

American Bosch Corporation, producer of automotive electrical equipment for over 40 years and the Nation's leading manufacturer of Diesel injection systems, entered the aviation equipment field just prior to World War II.

A major producer of farm and industrial magnetos, American Bosch had successfully developed aircraft magnetos when World War II erupted and, during one period of the War, was producing units for the Armed Forces at the rate of over 50,000 per month.

It was during World War II that American Bosch also developed the aircraft starting vibrator for cold-engine starting, and a considerable amount of experimentation development work was devoted to gasoline injection systems for aircraft engines.

With aircraft magnetos and starting vibrators still an important part of its production, American Bosch, in the past several years, has substantially increased its activity in the aircraft equipment field. Today, American Bosch produces fuel nozzles, overspeed governors, and fuel and exhaust control devices for jet engines; antisubmarine searchlights for Naval aircraft; and nickel cadmium batteries for aircraft applications.

Research and development work at American Bosch continues at a rapid pace. The industry, therefore, can look to American Bosch for other new and improved aircraft equipment as it reaches the production stage.

AMERICAN HELICOPTER COMPANY, INC.

Manhattan Beach, Calif.

The American Helicopter Company was incorporated in the State of California in 1947. This Company pioneered the development of successful pulse-jet engines for rotary-wing aircraft. Other early programs included engineering studies of facilities, trainer-demonstration devices, centrifuges, various types of pulse-jet engines, and pulse-jet-propelled helicopter rotor systems.

AHCo pulse-jet engines are the first such engines to pass Official Air Force Preliminary Flight Rating Tests and be accepted for use on piloted aircraft. The maintenance-free period of endurance, approximately one-half hour in 1947, is now considerably in excess of 100 hours. Comparable improvements have been made in minimum specific fuel consumption and increased allowable *g* loading. An integral starting system has been developed which permits quick reliable starts of the engines.

Present power-plant development programs are directed toward further improvement in performance, noise control, and functional maintenance characteristics through the use of advanced types of intermittent jet power plants.

The XH-26 "Jet Jeep" Helicopter, developed by American Helicopter, is considered to be the first successful military-type jet-propelled helicopter. The principles that have been proved on the XH-26 are presently being applied to considerably larger helicopters.

The cabin air pressurization system developed and manufactured by AiResearch, Los Angeles, for the Boeing B-52, involves use of air shut-off valves which must operate under extreme temperature – *and without fail.* The 2½" valve above, for example, operates at temperatures to +746°F., and pressures to 205 PSIG, and is part of the vital air regulation system.

To control the actuator which opens and closes this air valve, PSP Engineering Company – working in close co-operation with AiResearch – developed a special "hot" solenoid for the job. It withstands both heat and cold encountered under the widely varying conditions of Stratofortress flight. Similar PSP "hot" solenoids are used for operating many other air valves throughout the system.

Whether your particular problem calls for putting solenoids on the "hot seat," or simply applying one or more of 220 standard PSP solenoid models to your valve actuating requirements, it will pay you to write for further data. PSP engineers will gladly work with you on your individual solenoid problem.

Send for your free copy of the informative PSP Catalog – today.

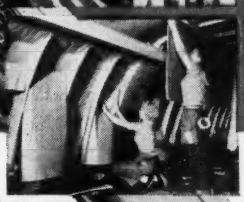
PSP ENGINEERING COMPANY
8420 Otis Street, South Gate, California
SOLENOIDS

Largest manufacturer on the Pacific Coast producing aircraft quality solenoids exclusively.

REFRASIL HITCO THERMO-COUSTI INSULATION

FOR THE DOUGLAS C-124 GLOBEMASTER

Heater ducts for the Anti-icing systems for wing and empennage are efficiently insulated with Refrasil Pre-formed High Temperature Insulating Blankets.



Thermo-Cousti Cabin Insulation Blankets being installed in the cargo cabin of the Douglas C-124.

Note in the photo below the smooth, well-fitted appearance of Thermo-Cousti Insulation Blankets after installation in the C-124.

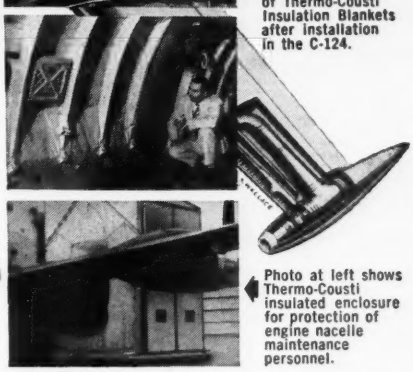


Photo at left shows Thermo-Cousti insulated enclosure for protection of engine nacelle maintenance personnel.

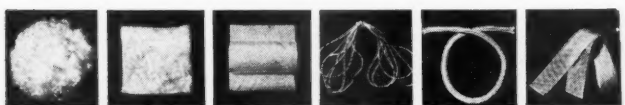
Insulation performs a big job in the Mammoth C-124 Globemaster. This sky giant, designed and manufactured by the Douglas Long Beach Plant, depends on HITCO Insulating Blankets for efficient thermal and acoustical insulation.

Thermo-Cousti Cabin Insulating Blankets protect 200 fully equipped troops against noise, heat and cold, in the huge 50,000 pound capacity cargo cabin. Refrasil Preformed High Temperature Insulating Blankets are fabricated of Refrasil Batt, sandwiched between two layers of .002" stainless steel foil. On the C-124 they are installed on the anti-icing Heater Ducts in the tail section and in the wing tips to conserve heat and protect surrounding structure. HITCO insulation is specified because of its lightweight and superior insulating qualities for high temperatures.

HITCO engineering counsel is available to you without charge to help you solve your high temperature or acoustical insulating problems. Write today for illustrated literature.

WRITE OR CALL YOUR NEAREST REPRESENTATIVE:

EASTERN	MIDWEST	SOUTHWEST
Fred W. Muhlenfeld	Burnie L. Weddle	Marshall Morris
6659 Loch Hill Rd.	3219 West 29th St.	3513 South Drive
Baltimore 12, Md.	Indianapolis 22, Ind.	Fort Worth, Texas
Valley 3135	Hickory 8685	Webster 2965



REFRASIL THERMO-COUSTI

HITCO

H. I. THOMPSON FIBER GLASS CO.
(Formerly The H. I. Thompson Co.)
1733 Cordova St., Los Angeles 7, Calif.
Telephone REpublic 3-9161

HIGH TEMPERATURE AND ACOUSTICAL INSULATION PRODUCTS

American Helicopter's XH-26 with skid gear and plastic aft fuselage.

The American Helicopter Company, Inc., is also engaged in the development and commercial manufacture of various electronic instrumentation and pulse-jet engine applications. A newly acquired subsidiary, Plastics Research, is engaged in the prototype development of various special fiberglass-reinforced-plastic products and other research programs.

AMERICAN PHENOLIC CORPORATION

Chicago, Ill.

Just as a chain is only as strong as its weakest link, so is an aircraft only as strong as its component parts. Airplanes have been flying for 50 years and for a good portion of that period, Amphenol has been producing superior, quality electrical and electronic components for those aircraft. Always in the foreground, working in close cooperation with aeronautical engineers both in and out of Government, the American Phenolic Corporation has made outstanding and lasting contributions to aviation progress.

Aircraft manufacturers and Government agencies long ago learned to depend upon Amphenol for both the development of new components and the production of standard parts of the highest quality. Government specifications, in countless cases, are but the reflection of results attained by Amphenol engineers in working out aircraft problems. When Amphenol develops a new component, the need for which has been demonstrated in the development of new tyes of aircraft, the chances are that such a new component will be the one specified as standard for future installations. This has been proved true so many times that it is almost axiomatic in Governmental and aircraft circles.

The development and perfection of coaxial cable, the expansion and general improvement of the AN connector, the introduction of the molded socket for radio prefocused sockets for landing field application, and countless improvements in cable and cable harnesses are but a few cases in point.

In addition, of course, to supplying the aircraft industry directly with necessary components, Amphenol also leads in supplying all types of instrument manufacturers with RF and other components for their products which ultimately end up as aircraft installations.

Amphenol engineers never rear back in their seats satisfied with their results; they are constantly searching for a new, more efficient component or a new method that will contribute to the ever expanding aircraft industry.

Even now two major improvements are being brought out by Amphenol: one, the new dielectric, Diallyl Phthalate, known as "Amphenol Blue" 1-501, is replacing melamine and other old-time insert materials; and the latest far-reaching change is the conversion to gold-plated contacts on all AN connectors. The advantages of gold-plated contacts are multiple, but the greatest asset is the indefinite stock-life given the connectors. Government depots may now store Amphenol AN connectors with no fear of deterioration from oxidation as happens with silver-plated contacts. Gold plating also makes soldering easier and faster, and it provides a superior contact surface both electrically and mechanically.

As previously stated, for 20 years Amphenol has been making steady and important contributions to aviation, and it fully expects to remain the leader in the component field for the next 50 years.

When Aviation celebrates its 100th Anniversary, Amphenol will be there.

AMERICAN STEEL & WIRE DIVISION, UNITED STATES STEEL CORPORATION

Cleveland, Ohio

The American Steel & Wire Division, since its first mill was built in 1831, has provided wire and wire products for many phases of American industrial and transportation development. It has not only kept pace but has pioneered many advancements for better living. Wherever wire is used one will find "A. S. & W. Div." a well-known and well-remembered name. Railroads, hoop skirts, telegraph, telephone, picture hats, automobiles, pianos, and streamlined trains are all representative of the diversification of industries it has served and is serving. They have, over the years, drawn upon its ability as a maker of wire, wire products, and strip to supply their needs.

The aircraft industry is one of the most promising industries American Steel & Wire serves. Its growth has been characterized by superlatives, and it has been pictured as the fastest growing industry in the history of our country, if not of the world.

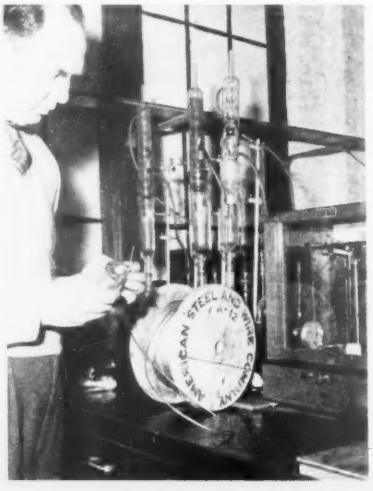
It has been American Steel & Wire's privilege to participate in this growth. Participation is of such a wide nature that it is sometimes difficult to trace it, particularly into aircraft component parts. However, by citing specific examples of aircraft and airports using A. S. & W. products, one may gain an insight into its efforts.

A. S. & W. also maintains many research laboratories that are constantly undergoing examination for better alloys and to aid the aviation industry in all types of metallurgical problems. In the airport category for instance, the company has furnished the New York Port of Authority with 15,000 tons of welded fabric for the great Idlewild International Airport, as well as for many other airports in the United States.

In the aircraft field, 10,000 ft. of A. S. & W.'s cable controls the flight of the B-36 intercontinental bomber, and its stainless steels find many applications in different airplanes, including the Sabre and the Constellation. It manufactures the higher strength cables that arrest Uncle Sam's fast Navy jet fighters aboard carriers, as well as many other types of steel that go into different airplane parts for fabrication.

A recent development of the research laboratories produced a nonmagnetic, high coefficient of expansion cable called Hyco-Span, which has helped solve many of the control problems and electronic problems of aircraft engineers.

The American Steel & Wire Division is proud of its contribution to aircraft and aviation progress and shall continue its efforts to better its products and continue its research for the advancement of aviation.



Eliminate 90 lbs. of deadweight with HYCO-SPAN CONTROL CABLES

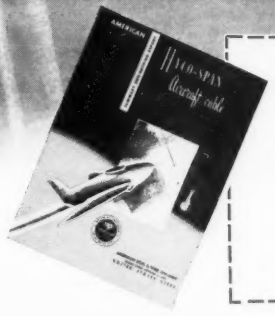
• When you zoom up to the stratosphere in a modern fighter, air temperature zooms *down* fast, and you need control cables that will contract right along with your air frame. Then you can count on tight, firm control of rudder and flaps, *without* the extra complexity and weight of temperature compensating devices.

American Hyco-Span Aircraft Cables can eliminate as many as four of these mechanisms: a saving in weight of about 90 lbs. The reason is that Hyco-Span has an extremely high coefficient of thermal expansion—50% higher than carbon steel and 33% higher than stainless steel. It comes closer than any other steel cable to matching the expansion and contraction of alloy air frames. As a result, Hyco-Span cables stay tight and give you accurate control without compensators.

What's more, Hyco-Span cables can be used in any climate, because they have the corrosion resistance of stainless steel. They last longer, because a *low coefficient of friction* permits lower cable tension. And they don't affect the accuracy of delicate electronic instruments, because they are non-magnetic.

Send the coupon for complete information.

AMERICAN STEEL & WIRE DIVISION, UNITED STATES STEEL CORPORATION
GENERAL OFFICES: CLEVELAND, OHIO
COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO, PACIFIC COAST DISTRIBUTORS
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA., SOUTHERN DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK



American Steel & Wire
Room 842, Rockefeller Bldg.
Cleveland 13, Ohio

Please send me, without obligation, a copy of your booklet "Hyco-Span Aircraft Cable" which describes all the important advantages of this control cable.

Name.....

Company.....

Address.....

City & State.....

DEPARTMENT OF TECHNOLOGY
BUFFALO, NEW YORK

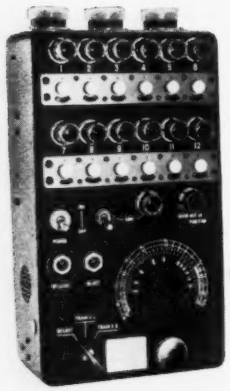
U·S·S American HYCO-SPAN Aircraft Cables

USS

UNITED STATES STEEL

NEWMATICS

RHODES LEWIS ELECTRICAL CONTROL BOXES CUSTOM MADE TO YOUR SPECIFICATIONS



Electrical control box units centralize and coordinate the management of remote equipment. Rhodes Lewis specializes in the design of compact light-weight control box units that require minimum installation effort. Typical innovations of Rhodes Lewis designs include: Edge-lighting for panel illumination without additional light source; intervalometer for continuous impulsing with a variable time interval of 7 to 120 seconds.

See Rhodes Lewis for these new light-weight products and systems

ITEM	Used in high-pressure pneumatic systems	Used in low-pressure pneumatic systems	Other aircraft applications
AC & DC Compressors	X	X	
Hydraulically Driven Compressors	X	X	
Bleed Turbine Compressors	X	X	
Fiberglass Pneumatic Receivers	X	X	
Electrical & Electronic Control Systems			X
AC & DC Motors	X	X	X
Small Accessory Turbine Drives	X	X	X
Pneumatic Valves, Operated Electrically or Mechanically	X	X	
Solenoids, Intermittent or Continuous Duty	X	X	X
Pneumatic Ejection Systems	X	X	

Take advantage of Rhodes Lewis engineering knowledge and manufacturing facilities in the field of electrical and pneumatic equipment. Your inquiries are cordially invited.

6-3301

RHODES LEWIS CO.

Subsidiary of McCulloch Motors Corporation

6151 W. 98th Street,
Los Angeles 45, California

ELECTRIC PNEUMATIC ENGINEERS·MANUFACTURERS

ANDERSON, GREENWOOD & COMPANY

Bellaire, Tex.

Anderson, Greenwood & Company recently received a contract for the design, manufacture, and installation of a new type of missile launching system to be erected at a missile test base. This contract resulted from preliminary studies undertaken a year ago investigating missile ground-support equipment.

Additional contracts are pending for missile components and auxiliaries, as well as a new type of augmented projectile that Anderson, Greenwood has independently developed.

Work continues on design changes and field installation kit drawings for the Boeing B-47.

Anderson, Greenwood & Company was organized in 1945 to design and produce personal aircraft in Houston, Tex. Model AG-14 was the company's initial design, a two-place all-metal pusher, first flown in 1947.

The first production airplane was flown in June, 1950. Rapid completion of CAA requirements brought the Approved Type Certificate in September. The four remaining airplanes were completed in 1951.

In March, 1951, contracts were signed with Convair for engineering design of major components of the R3Y turboprop flying boats. Increasingly heavy responsibilities were undertaken on these projects until completed in early 1953.

Work continues on additional contracts signed in 1952 with both divisions of the Boeing company.

Rapid expansion has allowed the company to build its own engineering and production facilities.

ARDE ASSOCIATES

Newark, N.J.

Arde Associates is an engineering corporation supplying engineering assistance to prime contractors in the research and development field. Facilities for the fabrication of prototypes, test items, and test equipment are available, and its offices and personnel are cleared for classified projects.

The staff includes experienced design and analytical engineers, physicists, and layout and detail draftsmen. Cumulative experience includes major work on aircraft and missile structures, rocket and jet engines, pressure vessels, servomechanisms and computers, controls, and instrumentation. The most advanced mathematical and analytical concepts and techniques have been applied in the work on unusual problems of structural analysis, fluid dynamics, and heat transfer.

In the rocket and guided-missile field, Arde Associates has designed extremely lightweight solid-propellant rocket cases for many of the major missile projects. In the aircraft engine field, present work includes structural analysis of a turboprop engine, analysis of cooling in a ram-jet, and the study of the stability of an inner body in a supersonic duct by means of scale models.

ASSOCIATED AVIATION UNDERWRITERS

New York, N.Y.

Associated Aviation Underwriters was organized in 1929 by Chubb and Son and Marine Office of America to serve as the Aviation Department of those companies for which they operated as Marine Departments. The original group has now increased to 60 members and constitutes one of the largest aviation insurance groups in the country, with combined assets of two and three quarter billion dollars. For many years Associated Aviation concentrated almost entirely on scheduled air-line and aircraft factory accounts and became the recognized experts in this field of aviation insurance. During that period Associated Aviation enjoyed the privilege of insuring the majority of the leaders in these two categories.

More recently, Associated Aviation has expanded its activities to include more private and industrial aid or corporate aircraft and now writes a substantial part of this business. During the years, Associated Aviation has made many contributions to the aircraft industry, not only through its constant effort to reduce the cost of aviation insurance and at the same time provide broader coverage but through its extensive engineering and inspection service and participation in many industry activities.

Associated Aviation was the first aviation insurance group to provide countrywide low-cost and convenient facilities for the purchase of air-line trip insurance at rates based upon the outstanding safety record of the scheduled air lines. These facilities include automatic coin-operated dispensing machines at more than 200 airports in the United States, Canada, Alaska, and Hawaii, as well as Air Travel Insurance counters at airports developing sufficient traffic to support this type of activity.

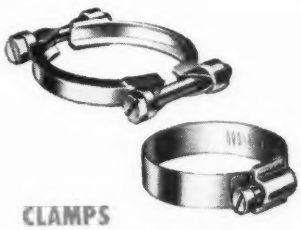
AVIATION ENGINEERING DIVISION, AVIEN-KNICKERBOCKER, INC.

Woodside, L.I., N.Y.

Too often in the past, the development of electronic controls has been in the direction of complexity and the ad-

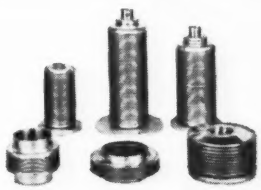
what's our line?

it's these BREEZE MARK precision products for industry...



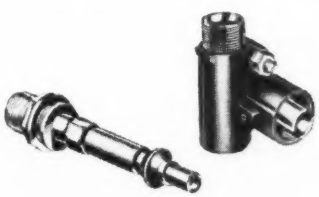
CLAMPS

From our famous AERO-SEAL Hose Clamps with precision worm gear drive—with scores of industrial uses—to custom-built special purpose clamps to withstand heavy pressures, extremes of temperature and vibration, and to resist corrosion. Any design, metal or quantity.



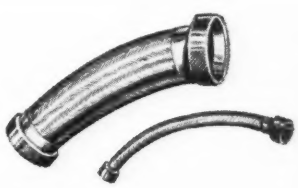
JOB ENGINEERED BELLOWS

Breeze special-design welded diaphragm bellows function where ordinary formed bellows fail . . . stand up longer under critical conditions of heat, cold, vibration and pressure. As expansion joints, steam lines, valve seals, switches, flow control and other applications.



SPECIAL PRECISION DRIVES

An outstanding Breeze specialty is special-purpose mechanical drives and transmissions, including Tee Drives, precision gear boxes and torque tube drives . . . all types of electro-mechanical actuators, built to meet rigid requirements of aircraft uses.



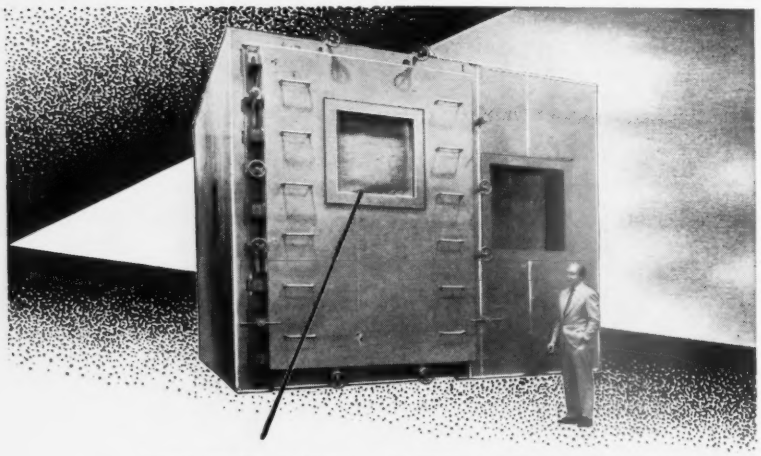
FLEXIBLE METAL TUBING

For electrical shielding, conduits and ducts, pressure lines, high and low temperature applications. Material, shapes and sizes to your specifications. This is our prime specialty. 25 years' experience.

Breeze is an engineering and design organization, with superb manufacturing facilities for precision equipment and custom-built components. We invite any problem in product improvement.

BREEZE CORPORATIONS, INC.

41 SOUTH SIXTH STREET, NEWARK 1, N. J.



"EXTRAS" ARE STANDARD WITH BOWSER

Bowser test chambers have the engineered "extras" as standard equipment. Bowser engineers have designed their units with your needs in mind.

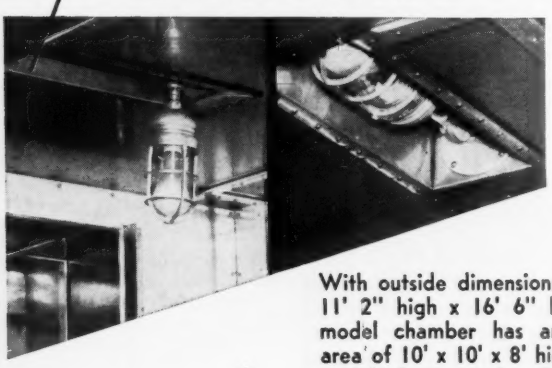
Consider, for example, lights in the Bowser high altitude chamber shown above. They are swivel type for convenient operation . . . vapor proof and recessed in stainless steel to permit full utilization of test area.

Performance characteristics of this Bowser chamber include:

Temperature range from —100°F to 185°F.

Altitude simulation up to 85,000 feet.

Evacuation rate of 5000 F.P.M.



With outside dimensions of 13' 2" wide x 11' 2" high x 16' 6" long, this standard model chamber has an interior working area of 10' x 10' x 8' high. Door is 5' wide x 8' high, its window 30" x 30", and wall window 36" x 36".

Whatever your needs in environmental test chamber equipment . . . high altitude, humidity, sand and dust, explosion, non-magnetic, etc. . . . check with Bowser, the pioneer.

BTR DEPENDABILITY

BOWSER TECHNICAL REFRIGERATION

DIVISION BOWSER, INC TERRYVILLE CONNECTICUT

dition of separate instruments to do specific jobs.

The need, on the other hand, has been for simplification of systems, for combinations of systems which can only result from an evaluation of total aircraft control needs.

The development of Avien capacitance fuel gaging systems has been in that direction.

The typical capacitance gage of 1945 consisted of five or more units and weighed about 10 lbs. Avien pioneered a lightweight capacitance gage design that reduced the weight to 5 lbs. Later, the units were reduced to three and the weight was reduced one-fifth. This year, a two-unit system was introduced that weighs less than 2 lbs.

Capacitance fuel gages have developed in 10 years from instruments of limited usefulness and accuracy to high-precision electronic systems designed for overall fuel management. They are, today, integral parts of indicating-control systems of high performance, and aircraft performance of the future will depend to an important degree upon continued progress in the direction of further integration of fuel management systems with overall controls.

BAKER STEEL & TUBE COMPANY

Los Angeles, Calif.

It was in the mid-twenties that the aircraft industry began to use seamless-steel tubing extensively as structural members in its planes. It was in 1926 that the California Panel & Veneer Company first placed a stock of aircraft steel tubing in its warehouse in Los Angeles. They, thus, were pioneers in this activity.

The steel end of the business later became a separate corporation, the Baker Steel & Tube Company.

Pacing the demand, Baker Steel & Tube Company constantly added to the range of sizes until, ultimately, sizes as large as $12^{3}/_{4}$-in. outside diameter by $1^{5}/_{8}$-in. wall, in alloy, were made available to aircraft builders.

With the advent of World War II, Baker's position as a distributor of aircraft steel tubing was so well established that they were selected as one of five companies in the United States to receive a Government contract to carry augmented stocks of this strategic material. At the close of the war Baker Steel & Tube Company retained this entire stock in order that service to the industry could continue unimpaired.

They now operate two warehouses with large stocks of aircraft alloy-steel tubing in a wide range of sizes and in a variety of grades.

Compact, powerful, custom-built A.C. or D.C. motors for ELECTRONICS and ELECTRO-MECHANICS

Wherever you need electric motors for maximum power in minimum size, Pesco has the basic co-ordinated frame sizes and power elements you'll require.

For example—Pesco motors are now in use for: cooling (blowers for electronic equipment), tuning (radios and automatic finders), scanning antenna (civilian and military), antiaircraft radar fire control, as well as pump drives and mechanical actuators.

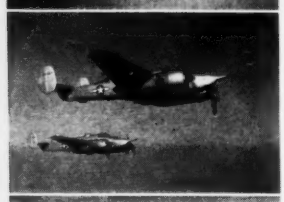
By using standardized parts in a series of six co-ordinated frame sizes, Pesco can provide you with electric motors for electronic applications with voltages from 6 to 120 volts D. C.; from 1/100 to 6 H. P. for operating speeds up to 15,000 R. P. M. Special, high-altitude design will operate from −65° to + 165° F.

Pesco high-frequency A.C. induction motors, squirrel-cage type, are built in a series of 5 co-ordinated frame sizes to meet horsepower requirements of .01 to 9.0, at 400 cycles per second.

Motors in these frame sizes can be built for *your* specific frequency, using standard parts to obtain the speed and power rating desired. Consult our Engineering Department concerning your requirements. Strictest confidence—and no obligation, of course!

engineering Pesco production
PRODUCTS DIVISION

BORG-WARNER CORPORATION
24700 NORTH MILES ROAD • BEDFORD, OHIO



BEECH AIRCRAFT CORPORATION

Wichita, Kan.

Back in 1925, when the airplane was a rare sight to midwestern eyes and flying was still groping along in its prep-school days, Walter H. Beech formed the Travel Air Company in the bustling plains city of Wichita, Kan., and began some of the most important developments in aircraft.

Within a matter of months after the company was formed, the late Walter H. Beech was setting a trend in aircraft design that down through the years was to set the pace for the leadership that Beech Aircraft planes have earned throughout the free world.

Even in that early aviation year of 1925, when Mr. Beech and his pioneering associates turned out three Travel Airs, the future progress of aircraft design was being established on a long-range basis. Those early Travel Air models represented the first plane ever to be equipped with a streamlined, faired-in engine cowling.

The first place honors those planes won were to set the pace for the many other honors Beech-designed aircraft continued to win in aeronautical competitions right on down the line of a long series of outstanding exploits of the air. Among some of these achievements are the following:

1925: Ford Reliability Tour. Three Beech-designed Travel Air planes entered. All finished with perfect scores.

1927: $25,000 Dole competition race, Oakland to Hawaii. Won by Arthur Goebel and William Davis in Travel Air "Woolaroc."

1929: On-to-Tulsa Derby. Won by Billy Parker in a Travel Air.

1929: Women's Derby, Santa Monica, Calif., to Cleveland. Won by Louise Thaden in a Travel Air.

1929: 50-mile Free-for-All Race. Won by Travel Air "Mystery S" piloted by Doug Davis.

1936: Beechcrafts won first, second, and fourth places in Unlimited Race for Frank E. Phillips Trophy at Denver's Mile-High Air Races.

1936: Louise Thaden and Blanche Noyes won first place in Bendix Transcontinental Speed Dash, flying a Beechcraft.

1937: New U.S. women's speed record—203.895 m.p.h.—set by Jacqueline Cochran in a Beechcraft.

1938: Macfadden Cross-Country Race, New York to Miami, won by Max Constant piloting a Model 17 Beechcraft.

1940: On-to-Miami Race for Macfadden Trophy won in Model 18 Beechcraft (H. C. Rankin, pilot; Walter H. Beech, copilot), 1,084 miles in 4 hours, 37 min.

1949: World record for nonstop distance flying for all light planes won by Capt. Bill Odom in Beechcraft Model 35 Bonanza, the "Waikiki Beech," from Honolulu, Hawaii, to Teterboro, N.J., March 7 and 8; 4,957.24 miles.

In 1953, Beech Aircraft Corporation observed its 21st year of progress by producing four Beechcraft models, for both military and civilian use, in facilities comprising about 2,000,000 sq.ft. of floor space in main plants at Wichita, Kan., and in satellite plants at Herington and Liberal.

The latest of a long line of efficient airplanes, whose design ancestry can be traced back to the streamlined planes Walter Beech first built in 1925, today's Beechcraft models include: the Model 18 eight-place, twin-engined transport; the Model 35 four-place, single-engined Bonanza; the Model 45 two-place, single-engined Mentor basic trainer; the Model 50 six-place, twin-engined Twin-Bonanza transport.

In 1953, the military versions of Beechcraft's models included production of the USAF C-45G, the USN SNB-5, the USAF T-34A, the USAF L-23A.

(From top to bottom, left) (1) First travel Air OX-5. (2) Woolaroc Travel Air monoplane. (3) Travel Air "Mystery S," 1930. (4) Model 17, No. 1, 1932. (5) Beechcraft D18S, all-metal executive transport. (6) XA-38 Grizzly. (7) Beechcraft Bonanza. (8) USAF T-34A. (9) USAF L-23A.

BELL AIRCRAFT CORPORATION

Buffalo, N.Y.

Prominent among the historic exhibits tracing the first 50 years of powered flight in the Smithsonian Institution are two distinguished contributions of Bell Aircraft Corporation which have helped to chart new frontiers in man's bid for conquest of space.

Now retired in the national aviation museum with such airplanes as the Wright brothers' ancient flying machine, the Spirit of St. Louis, and the NC-4 of early transatlantic fame are the Bell XP-59A, the nation's first jet fighter, and the rocket-powered Bell X-1, first plane in the world to fly faster than sound. These aircraft, each of which ushered in an important new phase of the aeronautical sciences, are among a number of aviation "firsts" claimed by Bell Aircraft.

When the X-1 was formally turned over to the Smithsonian on August 26, 1951, Gen. Hoyt S. Vanderberg, then Chief of Staff for the Air Force, declared: "It will be an example of what can be accomplished through the com-

The FUEL goes 'round and 'round and comes out CLEAR

HYDRO-AIRE MANUFACTURES:

- Hytrol Anti-Skid Braking System
- Fuel and Hot Air Valves
- Electro-Mechanical Actuators
- Fuel and Hydraulic Pumps
- Jet Engine Accessories
- Hydraulic Valves
- Turbo-Drive Units

THE HY-V/L^* FUEL BOOSTER PUMP BEATS THE PROBLEM THAT "MAKES AN AIRPLANE'S BLOOD BOIL"

HYDRO-AIRE *Inc.*

BURBANK, CALIF. • *Subsidiary of Crane Co.*

Every Fighter,
Every Bomber, Every Transport
is Hydro-Aire Equipped.

It is now several years since Hydro-Aire turned the attention of its Engineering Staff and Research Facilities to the dangerous phenomenon of vapor stall characteristics in Fuel Systems at altitude.

Preliminary consultations with leading aircraft companies led to an intensive research program. In the course of this research an entirely new principle was developed. The result of this new approach is the HY-V/L^* Fuel Booster Pump. Instead of the unwelcome fuel vapor being separated, it is forced back into liquid form *in the pump.*

Proof again that there are few projects too large . . . no project too small...for Hydro-Aire's unrivalled research facilities.

**Vapor-liquid ratio*

bination of American engineering, scientific, and military talent."

General Vandenberg said that the first supersonic flight of the X-1 on October 14, 1947, "marked the end of the first great period of the air age, introduced when the Wright brothers built their flying machine.

"I consider the X-1 the most convincing evidence of our ability to discover and control the forces of nature since the original Wright brothers' airplane," he added.

Bell Aircraft, which started from scratch with $150,000 solicited capital 18 years ago and had 56 employees at the end of 1935, was depression-born, war-expanded, and postwar retrenched. Its growth and progress have been an answer to the challenge of modern aviation.

Bell continues to work toward technical excellence and productive efficiency. Products bearing its trademark have distinguished themselves around the world.

But the complexion of Bell's engineering division has changed radically in the face of its new assignments.

Where once aeronautical engineers, designers, and draftsmen were the basic personnel, new advances in self-contained missiles and gaseous and liquid-propellant rocket engines now require specialized skills in physics, electronics, servomechanisms, radar, metallurgy, chemistry, radio, television, and telemetering, to mention a few.

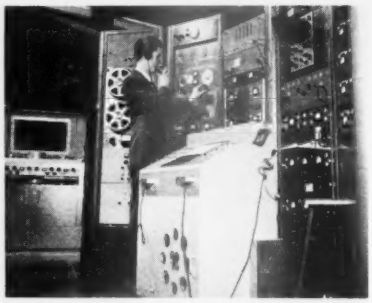
Bell's engineering force, incorporating the widest available knowledge and skill, has grown to approximately 3,300, nearly one-fourth of the total employment. By contrast, during World War II when employment topped 50,000, the number of engineering personnel reached a peak of 700.

A total of 6,000,000 engineering manhours was devoted exclusively to research and development of guided missiles, rocket engines, electronic components, and other scientific programs in 1952.

The most significant development in Bell's diversified engineering and scientific programs occurred in electronics. Efforts in this field alone increased nearly 50 per cent last year, and the number of electrical engineers engaged in this work climbed 80 per cent over the level of October, 1950.

A portion of the company's electronic activity is applied to the design and manufacture of autopilots for guided missiles and helicopters, and they vary in size from a compact unit for air-to-air guided missiles to powerful units for large supersonic missiles and airplanes.

A major share of electronic development and production is applied to the various radar devices that are required



One of the several telemetering ground stations used by Bell Aircraft to receive and record data during flight tests of airplanes or guided missiles.

in the navigation and guidance of airplanes and missiles. Another field of electronic development in which Bell is active is telemetering—the transmission of instrument measurements from airplanes or guided missiles to recording equipment on the ground.

Bell Aircraft has grown up with so-called aviation "firsts."

To begin with there was the Airacuda, first twin-engined escort fighter to mount a 37-mm. cannon in flexible gun turrets and described in 1937 by Gen. H. H. (Hap) Arnold as the "most striking example of airplane development anywhere in the world."

Then came the P-39 Airacobra, the first American fighter plane designed around its armament. Bell built nearly 10,000 of these superb fighters and at the end of World War II was producing an improved version, the P-63 Kingcobra.

When a shortage of aluminum threatened the industry, Bell designed and developed the XP-77, first modern all-wood military fighter.

Then, as the nation began to expand its big bomber program, Bell took over a huge plant in Georgia and built, flight-tested, and delivered 663 Boeing B-29's by the middle of 1945. In Vermont, it turned out more than 400,000 Bell-designed machine-gun mounts, as well as mortar shells and other armament for the military.

Yet, despite this all-out defense effort, Bell continued to emphasize experimental work, such as the P-59 Airacomet which was to open a revolutionary period in American aviation—the jet age. Bell was assigned the job of building the air frame in which was installed engines developed by General Electric and fashioned after the British Whittle.

The P-59 successfully completed its maiden flight test October 1, 1942, at Muroc, Calif., just a year after it was born on the drawing boards.

Another aviation milestone was reached when the Bell X-1, which went into flight from the drawing boards without a single design modification, made world history over Muroc Dry Lake when it became the first plane to pierce the sound barrier.

Even during the general postwar slump Bell continued work on its high priority project, developing a new and improved version of the X-1, the bigger X-1A, and the jet-propelled X-5, first plane capable of varying the degree of wing sweepback in flight. The latter was the only entirely new aircraft unveiled by the Air Force in 1951.

Both are supplying valuable service to the Air Force Air Research and Development Command in obtaining data for the further development of the nation's high-performance aircraft. The company currently is at work on still another plane in the special research aircraft series for the Air Force—the X-2.

When hostilities began in Korea in June, 1950, Bell's development programs were accelerated and production schedules were multiplied. Placed at the disposal of United Nations' forces was the radio-guided Tarzon bomb and the Bell helicopter. Bell already had pioneered in the commercial application of remote radio control and had been producing helicopters for 5 years. Thus, it was well qualified to supply the military at such a critical period.

One of the most gratifying chapters in company history was written by Bell helicopters in Korean combat. By the time a truce was signed, Bell helicopters had evacuated more than 15,000 wounded troops from the front lines—some from within enemy territory.

Today, the resourceful craft—a "jack-of-all-trades" used by the military and commercially in more than 30 countries in both hemispheres—holds a promising future for Bell.

Necessary expansion in 1952 resulted in the shifting of the company's entire helicopter operation to Texas. Production set new records, and last year Bell built more commercial helicopters than all other manufacturers combined.

Bell was awarded the world's first commercial helicopter license in May, 1946, just 4 years after the company undertook its initial experimental rotorcraft project, which was completely divorced from the job of producing fighter planes. One of the latest products of Bell engineering ingenuity is a high-powered antisubmarine helicopter for the Navy, design for which was selected over nine other companies.

Many of Bell's engineering contributions to aviation progress seemed as fantastic as the Wright brothers' famous flight a half century ago. But these concepts became a reality and have helped to prepare and equip civilization for assault on the unconquered frontiers of flight.

DC-7

the latest and greatest Douglas achievement

The new DC-7, another in the long list of firsts credited to the Douglas Aircraft Company, sets new standards of passenger comfort and convenience.

Powered with four Wright Turbo-Compound engines and using the Bendix* Direct Injection Fuel System, this new giant of the airways is the fastest of Douglas' long line of great transports.

Every detail of interior trim, every mechanical improvement in this great new plane has been designed to make flying as pleasant as possible.

Over the years the challenge of faster schedules at lower operating costs has been met by Bendix Products through the development of more efficient fuel metering. Problems of landing heavier loads at higher speeds have likewise been solved with efficient, high strength and low weight Bendix brakes, struts and landing gear.

*REG. U. S. PAT. OFF.

BENDIX DIRECT INJECTION FUEL SYSTEM

Lowers maintenance costs • Gives longer engine life • More engine power • Better altitude performance and engine acceleration • Easier starting • Shorter warm-up periods • More payload or more ton-miles per gallon

BENDIX • PRODUCTS DIVISION • SOUTH BEND Bendix AVIATION CORPORATION

Export Sales: Bendix International Division, 205 E. 42nd St., New York 17, N. Y.

BENDIX AVIATION CORPORATION

Detroit, Mich.

The story of Bendix Aviation Corporation, observes President Malcolm P. Ferguson, begins with an idea in a garage mechanic's mind.

But what gives the story its zest, Mr. Ferguson adds, is that what was once just an idea in a garage mechanic's mind is now a vastly diversified business—with a volume of over $500,000,000 a year and 24 operating divisions.

What one man started now employs over 47,000 people and is the investment of 28,000 stockholders. The original one-man engineering department now numbers over 6,000 people and will spend this year, for engineering alone, more than $60,000,000. And three original products have now been expanded into more than 650 broad, basic product activities.

The garage mechanic was named Vincent Bendix. His idea was to make a strange screw-thread-and-pinion device that would be an automatic starter drive and eliminate forever the hand cranking of automobiles. Back in 1913, Bendix joined forces with a little company in Elmira, N.Y.—the Eclipse Machine Company. Eclipse made bicycle coaster brakes, which contained a screw-thread steel part made with the kind of know-how Bendix was looking for to mass-produce his starter drive.

Eclipse's engineering department had just one man—the boss. Yet Eclipse in 1914 produced 5,500 Bendix starter drives and by 1919 was turning out half a million per year. The tremendous spurt that these drives gave to the automobile industry—which found them to be just the device needed to make an electric starting motor practical—did much to help put the entire nation on wheels.

Success of the starter drive in the early 1920's brought capital to Vincent Bendix and Eclipse Machine.

Eclipse, in 1923, acquired a small electrical business headed by a group of young men—three of whom are now vice-presidents of Bendix Aviation—which in 1926 produced the first inertia electric starting device for aircraft engines. Their aircraft starter, which got a flywheel whirling and then used the suddenly applied force of its rotation to crank the engine, was the beginning of the "aviation" part of Bendix.

Vincent Bendix, meanwhile, started a factory in South Bend, Ind., to produce another "first" for the booming American automotive industry. This was the four-wheel brake. The brake business was so successful that in 1928 Vincent Bendix bought out the Eclipse business in Elmira, and in 1929 Bendix Aviation Corporation was formed.

Besides Eclipse and the Bendix South Bend brake factory, there were other key companies involved in the new corporate merger whose industrial background was to contribute heavily to the highly diversified oragnization which is Bendix in 1953.

These were the Scintilla Magneto Company, producer of aviation and automotive ignition equipment which was already a world standard, and Stromberg Carburetor, a leader in aviation and automotive carburetion since 1907.

In its first year and during the early thirties, the Bendix corporate family continued to expand—adding some names of great promise in aviation, communications, and other fields of science.

Among them were Pioneer Instrument, world's largest manufacturer of aircraft instruments; Eclipse Aviation, leading maker of starters, generators, and electrical accessories for aircraft; Friez Instrument, for a great many years the nation's biggest manufacturer of meteorological instruments; Zenith Carburetor; and Bendix Radio, which had been an affiliated company.

Several smaller companies were also acquired, launching Bendix in such fields as hydraulic brake systems, vacuum power brakes, brake linings, automotive test equipment, and many others.

The tough, depression days of the thirties were for Bendix a decade of research that paid off, a decade when Bendix put over $6,900,000 into engineering research at its South Bend plant alone.

Bendix engineers developed their brakes into hydraulic and vacuum power systems for trucks and buses, experimented with passenger car power braking and power steering—a field in which they lead today. They tackled the much tougher braking problem of stopping ever faster and heavier aircraft, developing complete landing-gear systems and struts along with hydraulic systems for planes. At Bendix Radio, revolutionary developments such as the aviation radio compass came off the drawing boards, ever finer radio communications were developed, and experiments went forward in a new-fangled science called radar—in which Bendix pioneered. Aircraft instruments were made with such precision and ingenuity that "blind flight" became practical and scheduled air lines attained rank as a major factor in national transportation. The Friez division of Bendix, working with the Government, perfected the balloon-borne "radiosonde" weather instruments, which were later a vital war weapon.

By 1939, Bendix sales had reached $40,000,000 a year, and it employed 9,600 people. But more significantly, it had established its present-day character as a company serving the entire field of transportation and communications—with special emphasis on automotive, aviation, and electronic products. The core of the company emerged as creative engineering combined with a technique for mass production sharpened continually by the highly competitive automotive parts industry.

With this triple-punch versatility, the company was ready for its greatest challenge: World War II. To detail Bendix's wartime contributions would require thousands of words. But the scope of its accomplishments can be summarized.

To meet defense requirements, Bendix had to reach $900,000,000 yearly output by 1944, expanding its volume over 22 times, and to increase employment from 9,600 to over 77,000.

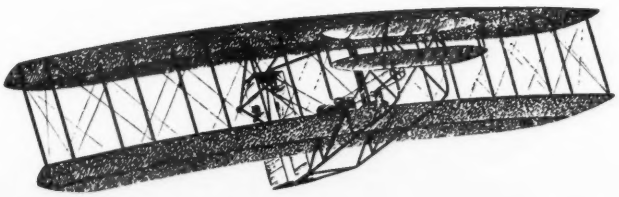
Production of key Bendix products—needed to start, stop, or control virtually every military vehicle that flies, floats, or moves on the ground—was pushed to astronomical figures. This involved round-the-clock production of many items machined finer than the finest Swiss watch.

There were, as well, many dramatic and unusual Bendix engineering developments before V-J Day: Navy GCA radar, the Gyro Flux Gate compass (first compass system that would perform accurately in aircraft in northern latitudes), the air-position indicator, the first all-electronic automatic pilot, a fuel injection system to fly aircraft at heights where ordinary carburetors were useless, automatic oxygen systems, four-wheel drives for jeeps, and scores of others. They were built to incredible precision, some to tolerances as fine as 10 millionths of an inch.

Vincent Bendix, who died in 1942, was succeeded at the helm of Bendix Aviation by Ernest R. Breech, now Executive Vice-President of Ford. Malcolm Ferguson, an engineer who has spent his entire business life with Bendix, took over the reins from Breech in 1946 and faced, as his first challenge, the titanic job of closing out $1,500,000,000 in war orders from the Company's books and readjusting the Corporation to a peacetime economy.

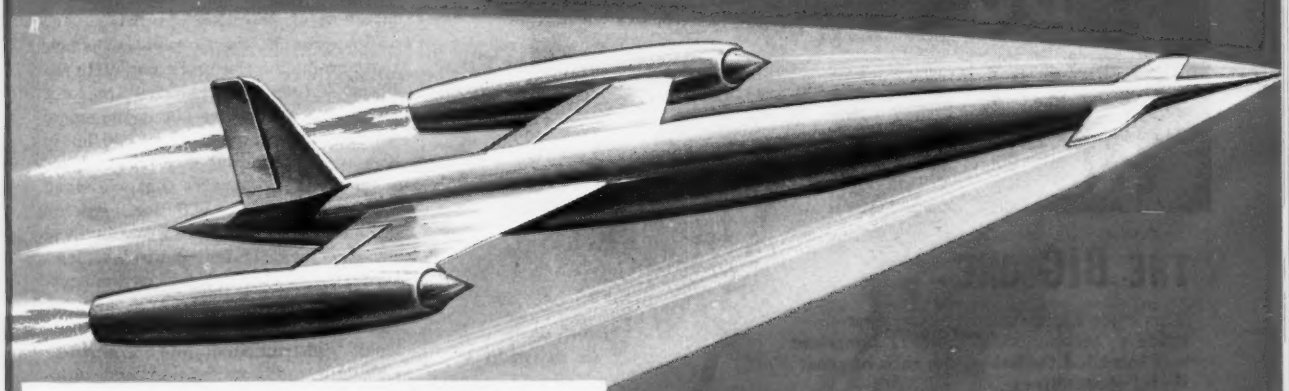
Largely an automotive business with regard to total sales volume before the war, and 90 per cent an aviation company during the war, Bendix in the mid-forties emerged with its activities roughly balanced between the aviation

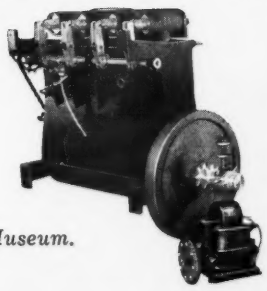
Wright Brothers *pioneers in piston power in 1903*



PROGRESS
50TH ANNIVERSARY OF POWERED FLIGHT
SECURITY

marquardt *pioneers in jet power in 1953*





The Institute of Aeronautical Sciences selected Marquardt engineers to produce the replica of the original Wright Brothers engine for permanent display at their Durand Aeronautical Museum.

Aviation has come a long way from the piston powered craft in 1903, pioneered by the Wright Brothers, to ramjet speeds of mach 4. Marquardt has been the pioneer in the research and development of ramjets, afterburners, air turbine accessory drives and thrust controls of advanced design. These units are currently in production to meet your requirements. Let us send you our illustrated engineering manuals.

marquardt AIRCRAFT CO.

ATTENTION ENGINEERS—Write today for full information concerning your future with Marquardt.

Van Nuys, California

DIALCO

for **YOUR** *product*

WHICH PILOT LIGHT DO YOU NEED?

ACTUAL SIZE
Cat. #613529-211

THE BIG ONE

This Pilot Light Assembly was first made to accommodate the *S-11 lamp* and was intended for use in the cabs of great diesel locomotives.

or

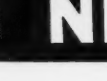
ACTUAL SIZE
Cat. #8-1930-621

THE LITTLE ONE

The miniaturization program on defense products required the development of this *sub-miniature* light. It is used on communication equipment and aircraft. Midget flanged base bulbs to fit are rated 1.3, 6, 12, and 28 volts.

Dialco HAS THE COMPLETE LINE of INDICATOR and PANEL LIGHTS

Samples to suit your own special conditions and requirements will be sent promptly and *without cost.* Just outline your needs. Let our engineering department assist in selecting the *right lamp* and the *best pilot light* for YOU.



Write for the Dialco HANDBOOK of PILOT LIGHTS

Foremost Manufacturer of Pilot Lights

DIALIGHT CORPORATION

60 STEWART AVENUE, BROOKLYN 37, N. Y. HYACINTH 7-7600

and automotive fields, with a smaller share representing industrial, consumer, and miscellaneous military products. But by 1948, the aviation side of the business again was climbing steadily—reaching about two-thirds of total volume by 1952—while automotive products accounted for only about one-sixth of all sales.

The climb in the Company's volume of aviation products reflected, of course, the Korean war, the new U.S. air power program, and the NATO military build-up. Bendix again expanded, establishing eight new manufacturing divisions, building new facilities at many existing divisions, and launching a broad subcontracting program.

But back of this expansion was Bendix engineering and research, which already, through the "plowing back" of millions of dollars into the business, had placed the Company in the front ranks of those who were solving the new complications of jet flight, atomic energy, aviation electronics, guided missiles, heavy radar, and hosts of others.

For example, the Corporation is now mass producing the first completely airborne self-contained starter for large jet engines—a starter about the size of a typewriter which develops 340 hp. in $3\frac{1}{2}$ sec. It produces jet-engine fuel systems, aircraft brakes that will stand a temperature of 2,000 deg., synchro units that are the heart of thousands of remote-indicating and control systems in modern aircraft, liquid oxygen converters, jet ignition that sparks at 15,000 volts, numerous gyro and electronic instruments and controls—including radio navigation and automatic pilot systems—and hundreds of others.

At Kansas City, Mo., Bendix operates a division whose entire activities are under contract to the Atomic Energy Commission, and at Mishawaka, Ind., it has built new plants entirely devoted to guided missiles. Telemetering—the radio transmission of information from missiles or aircraft to the ground—is another Bendix specialty.

This expansion was pressed forward while Bendix continued to serve its civilian customers, aviation and automotive, and even to perfect new engineering developments—such as automotive power steering and braking—in these fields.

On the 50th Anniversary of Powered Flight, Bendix products by the score are basic to plane performance, pilot efficiency, and safety—basic to the development of modern aviation. Older Bendix men, who look back on the profound revolution in aviation from the "fly-by-the-seat-of-your-pants" era of World War I to today's scheduled all-weather flights, find that they played a crucial role in this great change.

THE BG CORPORATION

New York, N.Y.

An outstanding example of a company that got into aviation during World War I and stayed is The BG Corporation. I was located in New York's financial district at the outbreak of World War I and one of its partners was a machinist named Brewster (of Brewster-Goldsmith, now BG), who headed experimental work for the Navy.

Up to that time there had been no spark plug able to stand up in the Liberty aircraft engine. With the assistance of limited test facilities made available by the Army and Navy, BG engineered and manufactured a new spark plug that proved entirely satisfactory. It was the 1XA, a nickel electrode, mica-insulated plug.

From the end of World War I to 1927, BG continued development and engineering despite a virtual stoppage of aviation development and, from 1927 on, has supplied aviation the world over with spark plugs and ignition products and systems. In addition, the company, early in the 1930's, developed a line of heavy-duty spark plugs for industrial engines. Constantly expanded over the years, this industrial line constitutes an important part of BG's business.

World War II found BG busy producing aviation spark plugs in large volume for the armed forces, as well as prime contractor to the Navy on component parts of the Variable Time Fuse. Several months before Pearl Harbor, ground was broken in Ridgefield, N.J., for a modern Ceramic plant, in which operations commenced in May, 1942.

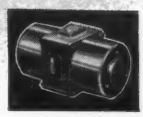
By 1933, BG had become one of the foremost manufacturers of aviation spark plugs and was devoting its facilities exclusively to the development and manufacture of spark plugs and related ignition products.

During the next few years BG developed and put into production numerous other aviation components such as gas-turbine igniters and thermocouples, as well as spark-plug elbows and terminal sleeves, test and service equipment, production of which is now a large part of BG's manufacturing effort.

Three additions have been made to the Ridgefield plant, including a modern production facility completed in 1953, where the entire manufacturing operation is presently being moved. The BG engineering and executive offices will remain at 136 W. 52nd St., New York, N.Y.

GYROS

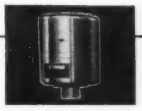
A new "Universal Series" Gyro is available in Free, Directional and Vertical types; as well as in composite Gyro sets comprising a combination of two units for sensitivity in three planes. ■ This series offers fast, remote caging that positively locks the gimbals in their normal erected position; remote uncaging; torque-motor erection; and unrestricted 360° rotation of both gimbals. Flexibility of design permits a choice of AC or DC rotors and synchro or potentiometer outputs. Reduced drift rate, greater life expectancy, and improved resistance to environmental shock, acceleration and vibration are incorporated in an instrument that is half the size of its predecessor...Size—Single Unit, 4" dia. x 5" long; Gyro set, 4" dia. x 8" long. *Write for complete engineering information.*



GYRO SET

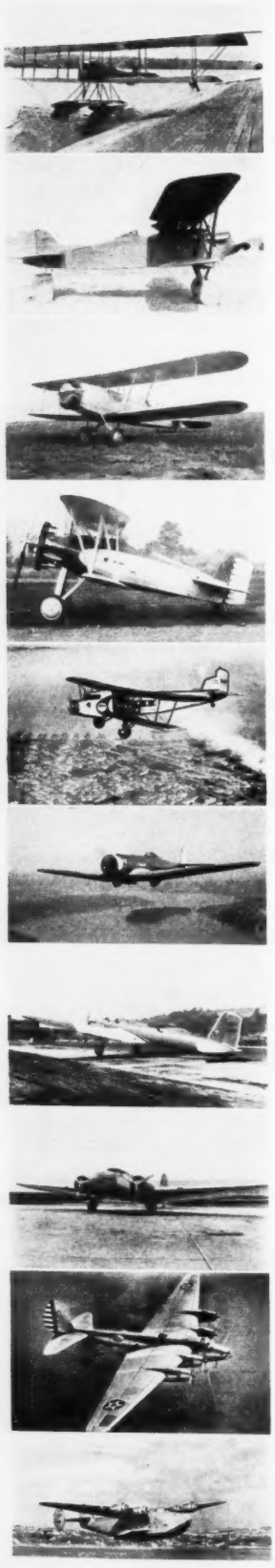
RATE GYRO

Giannini



DIRECTIONAL GYRO

G. M. GIANNINI & CO., INC. • PASADENA 15, CALIF. • EAST ORANGE, NEW JERSEY



Top to bottom (left): The B & W of 1916; the XPW-9 of 1924; the 40A of 1927; the XF4B-1 of 1928; Model 80 of 1928; the Monomail of 1930; the X1B-9 of 1931; the 247 of 1933; the XB-15 of 1937; the 314 of 1938.

BOEING AIRPLANE COMPANY

Seattle, Wash.

From a single "stick-and-wire" biplane to mass production of jet bombers in 37 years—that's a thumbnail sketch of Boeing Airplane Company. At its vast plants in Washington and Kansas, 56,000 persons—including more than 5,000 skilled engineers—are producing bombers, transports, missiles, gas-turbine engines, and many other products.

One of the largest aircraft companies in the world . . . and one of the oldest in the United States . . . Boeing started in business in 1916 with the production of a seaplane trainer. Since the tiny "B & W," the company has produced more than 21,000 airplanes. The famed B-17 Flying Fortress, the B-29 and B-50 Superforts, the C-97 Stratofreighter, the air-line Stratocruiser, the B-47 Stratojet, and B-52 Stratofortress are some of its more famed products. In the commercial field Boeing pioneered in developing the Model 40-A, first used in transcontinental air-mail and passenger flying; the sleek Monomail; the 247 twin-engined transport; the pressurized Stratoliner; and the Model 314 transoceanic flying boats.

Boeing Airplane Company today is building a new jet prototype airplane, the basic design of which will serve to demonstrate jet capabilities in each of three types of operation. Scheduled to fly in the summer of 1954, it will be adaptable to two production models—a high-speed transport for the commercial air lines, and a versatile military aircraft for both transport service and aerial refueling.

In research facilities, Boeing long has been a leader. It has the largest privately owned supersonic wind tunnel in the nation, and complete laboratories studying all phases of aviation from radar antennas to complex structural uses of new metals and materials.

Top to bottom (right): The 307 Stratoliner of 1939; the B-17G of 1943; the B-29 Superfortress of World War II and Korea; the Stratocruiser of 1949; the B-47A Stratojet of 1950; the YB-52 of 1952; the KC-97F of 1953; Artist's sketch of three Boeing jet transport design studies; the the F-99 "Bomarc" pilotless interceptor.

BOOZ, ALLEN & HAMILTON

Chicago, Ill.

Aviation is big business. Therefore, one service rendered by Booz, Allen & Hamilton is to provide constructive counsel to the management activities of the aviation world—both private industry and Government.

Aviation business has a unity rarely found in other industries. The dominant dependence on Government programs and continuing constructive interplay between companies give it peculiar status among industries. Therefore, the successful executive must know both aviation and management—as must his consultant.

Booz, Allen & Hamilton has programmed specifically against this need. Since 1940, the firm has applied its management experience specifically to aviation, opening with a large air-freight study. Since then, the firm has worked repeatedly with well over half of the major producers, as well as with air lines, maintenance facilities, and producers of accessories. The work directly for the Air Force, Navy, and Army continues.

Aviation is a highly technical field. A second service has been in developing new methodologies for the evaluation of technical operational and economic feasibility of major systems. This work, done both with industry and military, is classified.

As aviation has developed, so has the need for expanding management concepts and practices. Booz, Allen & Hamilton is grateful for being permitted to participate. It is also pleased that it has been called by some "the management consultants to the aviation industry."

BREEZE CORPORATIONS, INC.

Newark, N.J.

Breeze Corporations, Inc., was organized in 1926 and, during its 26 years of existence, has pioneered in the design and manufacture of many aircraft parts and accessories including the following:

Radio Ignition Shielding and Secondary Shielding.—Breeze has supplied shielding for the ignition systems of practically every major aircraft engine used in the industry. Because of the necessity for accurate radar communication between the ground and the air, good shielding of electrical circuits is mandatory, and the Breeze Engineering Department has designed shielding to meet the ever changing requirements.

In addition to designing systems for aircraft engines, Breeze manufactures and supplies a wide variety of flexible shielding conduit for use on secondary electrical systems. This conduit is furnished in many sizes and materials, including stainless steel, mild steel, brass, and aluminum. Fittings for use with this conduit are standard items, which the company regularly supplies.

Actuators and Gear Boxes.—Breeze was among the first to design and produce mechanical actuators for use in controlling rudders, ailerons, and other control surfaces. Since the production of the first units, Breeze has designed a wide variety of gear boxes, drives, electrical actuators (both linear and rotary) and also hydraulic actuators for use in aircraft.

Electrical Connectors.—To meet the exacting problems of the aircraft industry, Breeze has for many years designed and supplied a wide variety of specialized electrical connectors, including connectors that can be engaged and disengaged quickly without removal of wires. Breeze also supplies connectors to resist corrosion, high temperatures, and other physical problems encountered during flight.

Wiring Assemblies for Jet Aircraft.—In cooperation with the leading manufacturers of jet power plants, Breeze has designed an extensive line of electrical control boxes and wiring systems which will operate under extreme conditions of temperature and elevation.

Flexible Metal Tubing.—One of the basic products that the company has manufactured for many years is flexible metal tubing. This is made of stainless steel, mild steel, brass, and aluminum and is adaptable for many aircraft and air-base uses.

Bellows.—Breeze has recently developed, and is producing, welded-type stainless-steel bellows for use as exhaust dampeners, vibration dampeners, slip joints, and valve seals. Tests conducted on these bellows indicate that they will function where normal commercial formed type bellows fail.

Aeroseal Hose Clamp.—This hose clamp is designed specifically for the aircraft industry and has found wide usage not only for aircraft but also for use on ground equipment.

Facilities.—Breeze has complete facilities for manufacturing, testing, and engineering a wide variety of products and is constantly carrying on research and development work to meet new aircraft requirements as they arise.

THE BRISTOL AEROPLANE COMPANY OF CANADA LTD.

Montreal, Canada

One of the world's oldest aviation organizations has initiated a major expansion of its already extensive aero engine overhaul facilities in Eastern and Western Canada which figures in the millions of dollars.

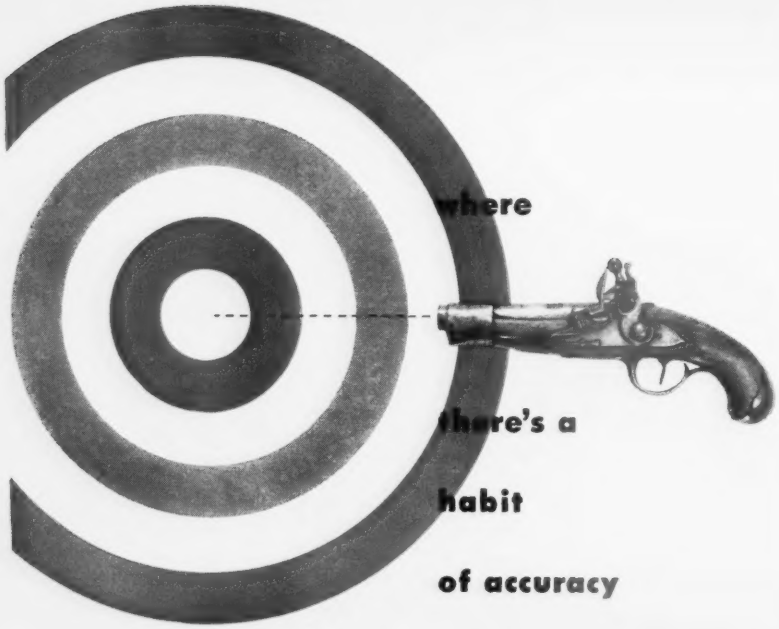
Boasting an enviable history dating back to 1910, The Bristol Aeroplane Company this month completes its second year of operations in Canada with its biggest single phase, the completion of a new $3,000,000 plant in suburban Montreal.

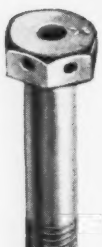
No. 1 blueprint of the Canadian company's future on this continent is based on the anticipated steady growth of aero engine demand and involves the investment of millions of dollars in plant, equipment, and facilities for not only overhaul and testing projects but also machine shop, engineering, and accessory and component work.

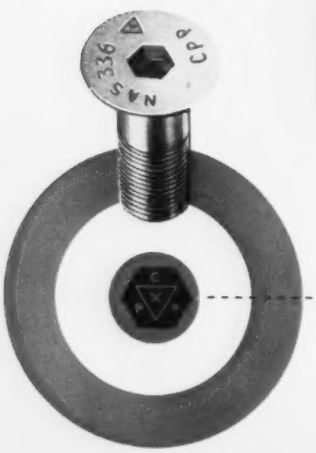
The productive years that began with the first flight of the Bristol Boxkite 43 years ago and which inaugurated a new era with the air-borne swiftness of today's superpowered Bristol Britannia have been witness to a succession of first-line Bristol aircraft and Bristol aero power plants which have made major contributions in not only two world wars but also in the more peaceful pursuits of world civil aviation.

The Bristol Aeroplane Company of Canada's three bases in this northern land—with head offices in Montreal's International Aviation Building and its two engine overhaul divisions on the west coast at Vancouver, B.C., and on the east coast at Montreal North—are evidence of Bristol's continuing policy of providing a world-wide service organization for its products.

The orderly rows of fashioned steel in the photo (published herewith), taken in the new Montreal aero engine plant in August 1953, are further evidence of the strength and permanence of Bristol's new-found roots for both defense and peace in North America and in democratic-minded nations the world over.







standards get special treatment

Daily production of fasteners for advanced and critical applications charts a pattern of high precision for the runs of AN and NAS standards which form more than half of Cooper's business, and receive a major share of Cooper's attention.

If it has to be "as good as a Cooper bolt," buy it from Cooper.

COOPER

precision products

5625 WEST CENTURY BOULEVARD
LOS ANGELES 45, CALIFORNIA

BROOKS & PERKINS, INC.

Detroit, Mich.

Brooks & Perkins was organized as a partnership on March 1, 1953 (incorporated July 1, 1947). At this time, the armed services were starting to use magnesium in substantial quantities. This company entered the magnesium field to meet the needs of the armed forces for a fabricating source for deep-drawn magnesium and magnesium assemblies. During the war years, capacity was devoted entirely to work for the armed services. Even since the end of the War, activities have been largely (but not entirely) devoted to Government contracts, including research and development projects.

Brooks & Perkins, Inc., offers complete fabrication facilities for magnesium exclusively, and their Livonia Mill Division has rolling mill facilities for supplying magnesium-alloy sheet and plate, both for military and commercial users.

Many of the radar reflectors, instrument housings, etc., commonly used in aircraft today are made of sheet magnesium and were originally made as prototypes by Brooks & Perkins. At the end of the War, when electronically operated fire-control systems developed by General Electric Company were adopted for bombers, Brooks & Perkins were called upon to design, loft, and build the first all-magnesium turret enclosures. They have been producers of many types of turret enclosures for General electric systems since that time.

Air-frame assemblies, ejection seat pans, rocket assemblies, ground heater chassis assemblies, radar reflectors and plotting equipment, air-cargo shipping racks, and kindred items have been made by Brooks & Perkins for several years. Wherever magnesium is used to reduce weight in aircraft and air-borne equipment, Brooks & Perkins are making parts, subassemblies, and assemblies.

CAL-AERO TECHNICAL INSTITUTE

Glendale, Calif.

With the ever increasing demand for engineers to man the ranks needed for production of aircraft in the United States today, Cal-Aero Technical Institute has made a contribution to the industry of aviation which deserves an important chapter in its history. By the device of graduating competent engineers within a 2-year course, it has been able to give the industry thousands of young men ready to take their places at the designing board along with others who have been obliged to devote the formal 4 years to the process. The

50 years of POWERED FLIGHT

Grand Central Aircraft Co. salutes Aviation's half century of historic achievement. It is only the beginning and as in the past, the impossible of today may be the obsolete of tomorrow. For one half of this period Grand Central has built and grown up with Aviation, through hard times as well as good. It is inspiring to continue to face forward to our share of the future with consistent quality workmanship and "pulling together" spirit, that assures deliveries to our country's defensive strength on schedule.

Opportunities in ELECTRONICS

Grand Central is seeking high caliber, experienced and qualified men of integrity, to participate in the long range B-47 stratojet modification program, at our Tucson, Arizona Division.

Full employee benefits and high salary scales, with living and recreational facilities are among the best anywhere in the country. Grand Central employees have found that their work over the past quarter century period has given them tremendous prestige—when you join the "Grand Central Family" you share in that prestige. You'll like the work with the "pulling together" spirit together with its excellent opportunities, based on merit and initiative.

MAIL THIS COUPON TODAY

Personnel Manager, Grand Central Aircraft Co.
Postoffice Box 5072, Tucson, Arizona

name

address

city and state

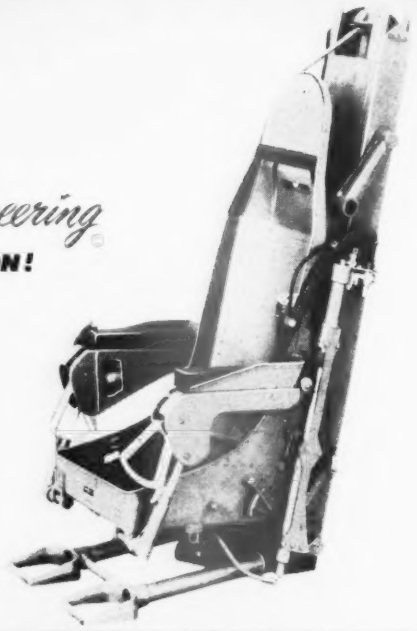
I am qualified in the category checked below and wish further information.

☐ Aeronautical Engineer ☐ Electronic Engineer
☐ Electronic Technician 5

GRAND CENTRAL AIRCRAFT CO.

GLENDALE, CALIFORNIA • • • **TUCSON, ARIZONA**
Grand Central Airport **Municipal Airport**

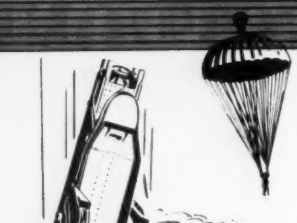
WEBER *Airgineering* IN ACTION!



"Safety... *when seconds count!*"

PROJECT 99 specified Ejection Seats for a new Jet Bomber. These had to be designed to Military Specifications for use by Pilot, Co-pilot and Navigator-Bombardier.

WEBER AIRGINEERING WENT TO WORK . . . complying with Military Specification MIL-S-6326, these seats were designed for 32Gs, while maintaining the lowest weight factor and bettering specification requirements. The electro-mechanical actuator gives complete uni-lateral adjustment for convenience and comfort. Ejection controls are in a compact enclosure in the arm rest, thus eliminating complex external linkages. One lever movement automatically performs the full complement of pre-ejection functions. A simple trigger squeeze accomplishes the ejection.



This is only one of many examples of how Weber airgineering works . . . if you have a problem why not take advantage of Weber's design-to-delivery service?

Airgineered by WEBER

WEBER AIRCRAFT CORPORATION

2820 Ontario Street • Burbank, Calif. • CHarleston 8-5543

Subsidiary of Weber Showcase & Fixture Co., Inc.

experience of 25 years went into the achievement.

It was accomplished by intense study and research among the leading engineers and industrial leaders of the nation, and the method thus adopted has proved its worth and value over the successive years. Thousands of Cal-Aero graduates have taken their place in aviation engineering immediately after completion of their 100-hour course, and the persistent call upon the school for its graduates from the leading aircraft builders is proof of its worthiness.

The elimination of all academic study not essential to the student's grasp of the practice and theory of aeronautical engineering is one of the chief reasons why the course has been successfully abbreviated. The combination of practical bench and shop work paralleling the lecture and text study is another. Further, the country has been combed to bring together a faculty of capable instructors devoted to this quick-training method.

CALIFORNIA PANEL & VENEER COMPANY

Los Angeles, Calif.

California Panel & Veneer Company is one of the oldest distributors of plywood in the country and pioneered in the sale of aircraft plywood on the Pacific Coast right after World War I. They supplied the plywood for the original Lockheed all-wood ship and many others.

About 1928, when chrome-molybdenum tubing was introduced, the Southern California Aircraft Manufacturers requested California Panel & Veneer Company to carry a stock of this material for their convenience. This developed into such a volume item that the Baker Steel & Tube Company was formed in 1935 to take over this phase of the business from the parent company.

During World War II, California Panel & Veneer Company was extremely active in supplying fabricated egg-crate construction, all-wood parts for aircraft, and plywood for gliders. This concern is now supplying the aircraft industry with fabricated parts made with metal honeycomb cores and, in its area, represents exclusively the Honeycomb Structures Company.

CANADAIR LIMITED

Montreal, Canada

Canada's largest aircraft manufacturer, Canadair, was originally established by the Canadian government and was managed on behalf of the Crown by the Canadian Vickers Ltd. In 1944, Canadair Limited was formed, and a year later negotitations for the acquisition of the Canadian company were initiated by the Electric Boat Company, of New York, one of the world's leading designers and builders of submarines.

In 1947, the American company purchased all the shares of Canadair. In 1952, the name of the Electric Boat Company was changed to General Dynamics Corporation, and this summer General Dynamics purchased the majority stock of Consolidated Vultee Aircraft Corporation.

During the war years, Canadair manufactured approximately 400 PBY flying boats for the Royal Canadian Air Force and the United States Navy. Subsequently, following the end of the war, Canadair produced more than 70 four-engined transport aircraft for Trans Canada Airlines, B.O.A.C., C.P.A., and the RCAF Transport Command.

In September, 1949, the Canadian government entered into a license agreement with North American Aviation, Inc., to build the Sabre in Canada. The production assignment went to Canadair and 11 months after the government's order, the first F-86A Sabre was shop-completed. Following this, the decision was made to change the air-frame configuration from the A to E series. This decision brought about changes that altered approximately 30 per cent of the original air frame.

Facilities at Canadair, hitherto devoted to producing four-engined North Star civil air liners and military transports, were quickly revised to accommodate this radically different project.

The company's first undertaking was to build five Sabre air frames a month, but with the increasing gravity of international affairs, the Sabre production rate was increased several times. To date, Canadair has supplied more than 600 of these fighter aircraft to the RCAF, RAF, and USAF. Current production models for the RCAF are now equipped with the Canadian-designed "Orenda" jet engine, which gives the aircraft increased performance at higher altitudes. Incorporating the Orenda engine in the Sabre necessitated complex design changes in the air frame of the aircraft.

In addition to the Sabre contract, Canadair also undertook to manufacture the Lockheed T-33 jet trainer for the RCAF. Again, design changes were made on the air frame in order to power the aircraft with the British "Nene" jet engine, and quantity production of the T-33 is now well underway.

C-47 and DC-3 spares are also being produced at Canadair in large quantities for some 100 air lines in 45 different countries, as well as for the RCAF and USAF.

During the past year, there has been considerable increase in the facilities of the company. There have been two warehouse buildings of 157,000 sq. ft. added; another plant of 200,000 sq. ft. on the northeast corner of the airfield has been constructed; and an additional final line and preflight hangar bay 200 by 800 ft. has been completed. These additions, with existing facilities, make a total of 2,250,000 sq.ft.

CESSNA AIRCRAFT COMPANY

Wichita, Kan.

The progress of an aircraft company is measured by the intelligent contributions of its engineering division. No other single group, in an airplane company, so controls the destiny of a concern as does the Engineering Group.

Cessna Aircraft Company has been fortunate in having a graduate aeronautical engineer as its President for a number of years—Dwane L. Wallace. Early in the life of the company, Mr. Wallace realized the importance of a strong engineering department and from the start gathered good engineers as the foundation of the company. His belief (and this belief has been proved thoroughly) is that, if the product excells in quality and performance, sales will be assured.

Cessna's development in the early thirties of the Model C-34, forerunner of the world famous "Airmaster" Series, was concrete proof that Mr. Wallace's thinking was based on solid ground. The "Airmaster" for several years was awarded the title of the "World's Most Efficient Airplane."

With war clouds on the horizon early in 1938, Cessna's Engineering Group developed the first of their twin airplanes, the Model T-50. Engineered to accomplish a multitude of duties, the plane was readily accepted by the United States Air Force and by other participating members of our Allied Forces for a twin-engined trainer and utility cargo ship.

From the drawing board to the flight line is often a long and tedious road for the engineers. This is especially true when developing entirely new models. To produce a flyable airplane from the drawing board with a minimum of malfunctions is the desire and purpose of an engineering group. However, this is easily said and not so easily done, but in the case of Cessna engineers this was accomplished in producing the Model 120 and Model 140 introduced shortly after World War II.

With the end of the war it was doubly important that this company return as competitors in the commercial airplane field as soon as possible. The number of Army and Navy "E's" received during the war for the quality of production was a nice memory to cherish but was

entirely overshadowed by the day's present problem—that of producing commercial aircraft.

With the rapid engineering accomplishments in producing the 120 and 140 behind them, Cessna's Engineering Division turned their attention toward a larger and more powerful Businessliner, the Model 170. Using the basic and proved configuration of the 140, Engineering Department designed a Model 170 that incorporated all of the better features of the 140, and an airplane that would comfortably accommodate four people.

In conjunction with the development of the Model 170, the Engineering Department produced a yet larger and more beautiful airplane, the Model 190. This aircraft incorporates a nine-cylinder radial engine, full cantilever wings and will accommodate either three or four passengers. This 190, like the Model 170, has become a standard of quality throughout the private aircraft industry.

Engineering's attention was then turned toward the military by the United Nations' entry into the Korean Conflict. The U.S. Army requested a versatile observation plane with flight characteristics better than anything that had been produced before. Within a record time Cessna's engineers designed the L-19. After exhaustive evaluation tests, Cessna was awarded the prime contract to build the L-19 in quantity. Powered with Continental 213 hp. engine and equipped with large Para-lift flaps, the airplane is capable of unusually short take-off run and short-field landings. Nicknamed the "Bird Dog," this aircraft is today a veteran in the Korean Conflict and is also used extensively throughout the United States as a training airplane.

Under research contracts with the Department of Navy, Cessna engineers are investigating the practical use of boundary-layer control on light airplanes. Engineering results on the Model 309, a converted Model 170, are pointing toward the practical application of boundary-layer control on both commercial and military aircraft.

At present, the Engineering Group in the Helicopter Division are developing a new concept in the field of rotary-wing flight. At the same time, under contract with the Department of Navy, they are working on a project involving design studies, experimental construction, and flight tests of helicopter rotor blades.

With corporate airplane users clambering for a speedy executive twin aircraft, Cessna engineered and is producing a twin with many engineering improvements that are incorporated in the configuration of the Cessna Model 310. Elliptical external wing-tip tanks for safety, low, flat, semimonocoque engine nacelles and concealed radio antenna are but a few of the features of the new twin. Many of these features are for the first time being used in the commercial private airplane field.

December 31, 1952, Cessna received a release from Department of Defense, Office of Public Information, Washington, D.C. This release was the first confirmation of the fact that Cessna had been awarded the contract for a new side-by-side trainer for the Air Force. This contract covered the design and construction of the first jet trainer specifically designed for the trainer mission. The following excerpt is taken from that release:

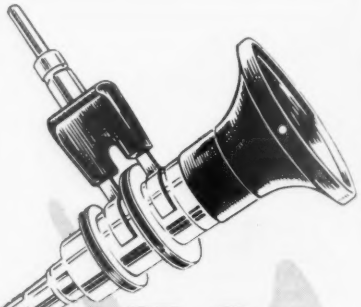
"The Cessna design was selected for further development from among 15 design proposals submitted by eight aircraft manufacturers. It will be the first jet trainer designed as such, to be developed for the Air Force. Jet Pilot training is now given in combat aircraft or modifications of combat types."

These concrete examples of engineering accomplishments have won the admiration and respect of the entire aircraft industry. "The progress of an aircraft company is measured by the intelligent contributions of its Engineering Division." Cessna is a progressive company.

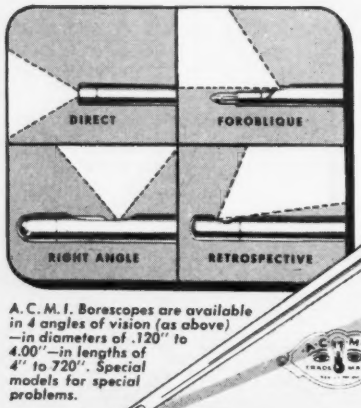
INSPECTION OF CONFINED AREAS FACILITATED

NECESSITY OF DISMANTLING AVOIDED

TIME SAVED—MONEY SAVED



A.C.M.I. BORESCOPES..



A.C.M.I. Borescopes are available in 4 angles of vision (as above) —in diameters of .120" to 4.00"—in lengths of 4" to 720". Special models for special problems.

The A.C.M.I. Borescopes permit close-up visual examination of interior areas and surfaces not otherwise visible. They save time and money, and prevent costly dismantling, by providing a practical solution to a wide variety of inspection problems.

In maintenance and inspection work, on small internal bores, machine parts or castings, to large boiler tubes, chemical plants, process equipment, or other industrial installations, an A.C.M.I. Borescope may be the answer to *your* problem.

Each Borescope is a compact, self-illuminated industrial telescope of highest quality, employing a precision optical system, that produces a flat visual field. Lens systems are fully corrected for color, spherical aberrations, and coma, with all lens surfaces coated to increase light transmission.

Write for free informational folder, or tell us your problem.

American Cystoscope Makers, Inc.

1241 LAFAYETTE AVENUE NEW YORK 59, N. Y.

DOW

MAGNESIUM CUTS DEAD WEIGHT, INCREASES HELICOPTER EFFICIENCY

Extensive use of DOW MAGNESIUM sheet, extrusions, and sand castings saves many important pounds on this versatile aircraft

When you have to go straight up from a standing start, weight saving is of prime importance. That's why designers of helicopters are making extensive use of magnesium, the world's lightest structural metal.

The range and capacity of one current production model helicopter have been greatly increased by the use of magnesium. In this ship the requirements of magnesium are equal to approximately 25% of the craft's total empty weight. This consists of 400 pounds of castings, comprising 90 different parts, and 700 pounds of sheet and extrusions, including nearly all of the fuselage skin.

The weight saved by the use of magnesium has helped increase the efficiency of helicopters. Where only yesterday these craft were novelties, today they are the real work horses of our armed forces.

Whenever you have a weight problem, investigate magnesium. One-third lighter than aluminum, magnesium offers you an exceptionally high strength/weight ratio. It is a practical metal, available in all common forms, workable by all standard shop methods. For complete information, call your nearest Dow office or write to: Magnesium Department, THE DOW CHEMICAL COMPANY, Midland, Michigan.

you can depend on DOW MAGNESIUM

DOW

CHASE AIRCRAFT COMPANY, INC.

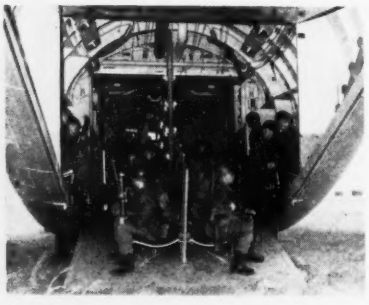
West Trenton, N.J.

A collection of notable "firsts" marks the 10-year corporate history of Chase Aircraft company, Inc.

First and thus far the only aircraft company to produce planes that meet the military requirement for assault transports, Chase presently is engaged in quantity production of the C-123B for the U.S. Air Force.

C-123B in flight.

Troops emerging from C-123B ready for immediate deployment.



Another view of the seating arrangement as seen from the foot of the ramp.

Loading of jeeps (backwards) via hydraulic ramp. The C-123B can carry five plus their crews.

Originally a glider manufacturer, Chase pioneered in the design and development of the assault transport principally because Chase engineers, under the guidance of the company's founder and chief engineer, Michael Stroukoff, successfully demonstrated the premise that all aircraft should basically be gliders in concept and adaptable for various forms of power.

The first American-developed jet transport was produced by Chase. It was the XC-123A, which made its initial test flight in West Trenton on April 21, 1951.

Chase is the only aircraft manufacturer that has produced a basic air frame performing successfully as a glider (G-20), as a conventionally powered piston-engined transport (C-123), and as a jet-powered transport (XC-123A).

Chase's initial ventures into the aircraft field concerned the design and development of two gliders, the XCG-14 and XCG-14A. Next, Chase produced the first all-metal cargo glider in aviation history, the XCG-18A, a craft that exceeded all specifications set forth by the Air Force. The XCG-18A made its first flight on December 18, 1947.

About this time, the powered assault transport became the goal of the military, and the rugged nature of the XCG-18A supported the logic of experimenting with the use of twin engined power for it. Less than 5 months after Chase received a contract, the YC-122 made its first flight on November 18, 1948.

Less than 11 months later, while production of a quantity of C-122's went forward, Chase flew the XC-123 for the first time. This was October 14, 1949.

In the summer of 1950 at Eglin Field, Fla., Air Force Evaluation Tests for assault transports were conducted. After weeks of gruelling competition, the XC-123 emerged with top honors and the YC-122 was second.

A service quantity of C-122's is operating presently with the 16th Troop Carrier Squadron (Assault) at Sewart Air Force Base in Smyrna, Tenn.

Increasing numbers of C-123B'S will begin to join the Air Force transport fleet in 1954. The C-123B carries 61 fully equipped troops and a number of combinations of trucks and weapons up to the size of a 155-mm. howitzer and can be converted in a matter of minutes into a "flying hospital." In the evacuation of wounded it can carry 50 litter patients, 6 ambulatory patients, and 6 medical attendants.

THE CHASE NATIONAL BANK OF THE CITY OF NEW YORK

New York, N.Y.

How have commercial banks contributed to the dramatic growth of the aviation industry?

Just as it took money to build and fly the first powered aircraft 50 years ago (the Wright brothers spent about $1,000 on Operation Kitty Hawk), it takes money to build and fly aircraft today—infinitely more money. That $1,000 would not cover more than half the cost of the tires on a modern intercontinental bomber.

Because of its faith in the growth potential of the aviation industry, the Chase National Bank made a point of associating itself with the industry many years ago. Since that time, as the industry has developed, Chase contributions, through loans and banking services, have grown apace so that at the present time Chase has credits extended to the industry totaling approximately a quarter of a billion dollars. The administration of the bank's relationships with the industry is handled by a special department staffed by men familiar with aviation and its particular problems, and it is believed that Chase is the only bank in the country to have a special department devoted exclusively to aviation.

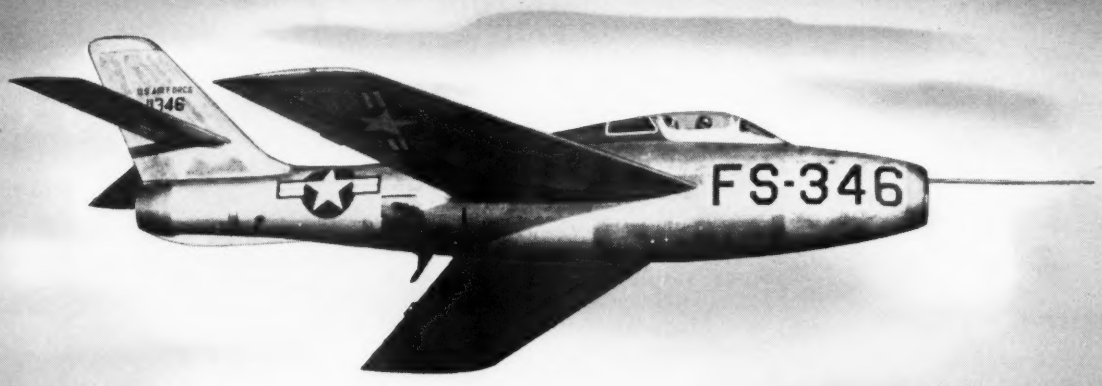
As a result of its early experience and continued association with the aviation industry, Chase has established itself as one of the most prominent banks, if not the leading one, in this field of financing. Its present relationships include practically all of the air-transport companies and manufacturers of aircraft and related components. Additional services rendered the industry embrace such things as Chase's present function as a clearing agent for the air lines in expediting and simplifying the monthly settlement of interline traffic balances. This service is also performed with respect to dollar clearings for IATA members.

The Chase, therefore, salutes the aviation industry on its 50th Anniversary and is proud of its part in helping to "keep 'em flying."

CIBA COMPANY, INC.

New York, N.Y.

The development of "landmark" advances in aircraft was typified by the de Havilland "Comet" and the Bristol "Britannia," utilizing, as they have, a synthetic resin for rivetless assembly of primary structures which has opened up a whole new concept in the aviation engineering mind that is only at the threshold of its eventual achievements.



REPUBLIC F-84 F THUNDERSTREAK

EQUIPPED WITH

WITTEK

Aviation HOSE CLAMPS

AN737-TW
TYPE WWD
(Tangential—
with one-piece
housing)

Standard of the Industry
for Over a Quarter Century

AN737-RM
TYPE FBSS
(Radial—with
floating bridge)

WITTEK MANUFACTURING COMPANY • 4305-15 West 24th Place, Chicago 23, Illinois

While the use of bonding resins has only recently come into its own for commercial aircraft production, Ciba's British affiliate, Aero Research Limited, under the guidance of Dr. N. A. de Bruyne, has pioneered and carefully carried forward this work since 1937.

The assembly of aircraft components of the "Redux" bonding process offers a number of outstanding advantages over other methods of assembly.

First, the weight of the structure is greatly reduced. In the case of the "Comet" and "Britannia," which were specifically designed to make most effective use of the "Redux" bonding process, it is estimated that the weight-saving resulting from the use of "Redux" is equivalent to the pay load. Elimination of the weight of rivets is only a minor factor in this weight-saving; much more important is the fact that the "Redux" process allows the skin structure to be stressed more completely and, hence, permits the use of lighter skin assemblies.

Fatigue strength (the limiting factor in aircraft life) is greatly increased, because the "Redux" bonds distribute the load uniformly over the entire area of contact between the parts being joined. Local stress concentrations around rivets or spot welded joints are eliminated.

Smooth exterior finish decreases air resistance—a feature of special importance in high-speed aircraft.

"Redux" joints are airtight. There is no need for special gasketing to prevent leakage in pressurized cabins or in integral fuel tanks.

Production costs are reduced. Since the presses used in the "Redux" bonding process are almost entirely automatic, dependence on the human factor is substantially reduced. There is less need for skilled or semiskilled labor. The entire joint is formed in one operation, which results in uniform strength. The "Redux" process also prevents the gradual misalignment that may occur in riveting along a row.

Design is simplified. Riveting design problems are eliminated, and resulting designs are cleaner.

"Redux" joints have high shear and peeling strength.

Here in the United States, the Cutlass F7U3 Fighter, built by Chance Vought for the U.S. Navy, is among the aircraft currently designed for the "Redux" process. The "Redux" process is also being utilized in the U.S. Navy's program of guided-missile development.

In all of these activities here and abroad, Ciba's research and technical service organization is working closely with the aircraft industry, so that the extensive background of engineering experience accumulated by Ciba in the application of "Redux" to aircraft can be usefully applied.

THE CLEVELAND PNEUMATIC TOOL COMPANY

Cleveland, Ohio

Long before the first flight at Kitty Hawk—even before the turn of the Century—Cleveland Pneumatic was producing compressed air tools of superior quality—tools that drove more rivets in a day or went down more feet in hard rock. Following World War I, the company moved forward into the manufacture of pneumatic-hydraulic shock absorbers for automobiles, trucks, and busses. These "air springs" experienced wide acceptance in the automotive industry and became distinguishing features on the finer cars of the twenties.

Cleveland Pneumatic's experience in successfully cushioning road shocks with air springs naturally suggested a similar device to absorb the landing and taxiing shocks of airplanes being produced in the growing aircraft industry.

The Aerol strut met immediate acceptance, and for a number of years Cleveland Pneumatic was the only manufacturer of the present accepted type of air-oil landing gear. As the aircraft industry grew, other concerns began manufacture of similar struts, many under license and technical assistance of Cleveland Pneumatic, who was and has remained "First in the Field."

Engineering research has continuously brought important improvements, and the company's contributions are indicative of its progressive growth in the past 50 years.

In more recent years, manufacturing techniques for using steel alloys at strengths up to 280,000 lbs. per sq.in. have been developed. The liquid spring shock absorber has been introduced as Cleveland Pneumatic's answer to increasingly severe space limitations The landing-gear testing laboratory duplicates the wing lift and spin-up effects of modern aircraft.

Cleveland Pneumatic has moved into the ball-bearing screw and actuator fields and in the past year has established a separate plant for actuator production.

The company's Automotive Division has made progress, increasing its production facilities for hydraulic unit lifts (transmission jacks) and for engine stands to meet the demand of both automotive and aircraft engine manufacturers.

In 1949, the company established pension trusts for its employees. During the past year, these trusts purchased all outstanding stock, making the company one of the few large employee-owned organizations in the U.S.

CLIFFORD MANUFACTURING COMPANY, DIVISION OF STANDARD-THOMSON CORPORATION

Waltham, Mass.

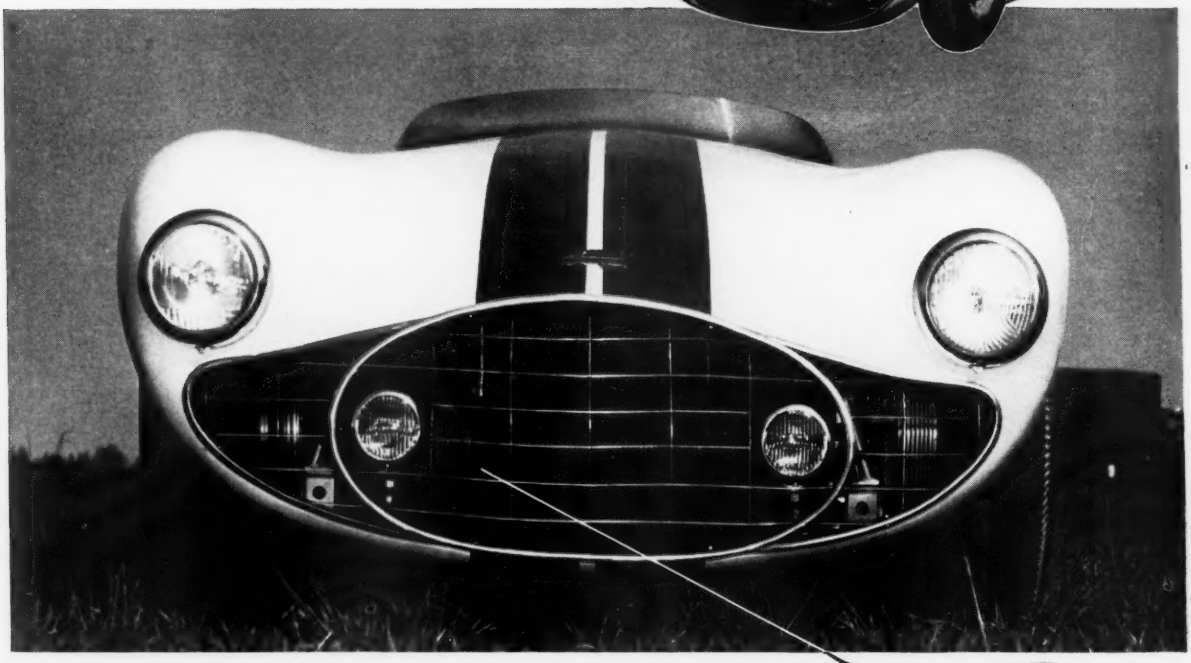
Clifford Manufacturing Company specializes in the production of high-quality products made from ultra-thin metals. It has developed special processes for making and assembling parts so thin that they are outside the range of normal manufacturing procedures.

Early in World War II, it became apparent that the weight of aircraft radiators and oil coolers must be reduced. Clifford Manufacturing Company made some thin-walled aluminum tubes and brazed them together to make a lightweight high-quality heat exchanger. These Clifford heat exchangers were two-thirds lighter than heat exchangers in use at that time and were therefore adopted for use on most military planes. In this program Clifford pioneered the all-aluminum tubular-type heat exchanger consisting of thin-walled tubes brazed to headers to secure maximum strength with minimum weight.

For gas turbines Clifford pioneered the idea of using fuel instead of air to cool the lubricating oil. This procedure reduces the size and weight of the oil cooler and also preheats the fuel for better combustion. But above all, it is important because it eliminates the aerodynamic drag inherent in air to oil cooling.

In order to be sure of their quality, Clifford has constructed the largest and most complete wind-tunnel test facilities devoted to aircraft heat exchangers and their components.

Clifford also produces metallic bellows, control valves, and other special items for the aircraft industry.



THIS LATEST CUNNINGHAM SPORTS CAR won its class and placed 3rd on distance in the grueling International 24-hour road race at Le Mans, France, in June, 1953. It *absolutely* cannot operate without an effective, lightweight oil cooling system — the engine bearings would burn out in less than one hour! That's why a Clifford 6" circular oil cooler, seen beside the right front brake drum, is essential. Cunningham engineers report it kept the oil cool during the entire 24 hours of racing — 2498.23 miles of road-pounding torture above 100 MPH average speed.

At any altitude... Clifford oil coolers are vital

In the air as on the ground, Clifford Feather Weight All-Aluminum Oil Coolers bring exceptional benefits to the protection of engine lubricating systems. For one thing, they're *the only all-brazed type of oil cooler*. Another big advantage is their superior weight-strength ratio — the result of Clifford's patented aluminum brazing method and pre-testing in the largest, most modern wind tunnel laboratory in the aeronautical heat exchanger industry. You'll find Clifford Feather Weights in every type of modern aircraft, military or civilian, jet or piston powered. For further details, write Clifford Manufacturing Company, 138 Grove St., Waltham 54, Mass. *Division of Standard-Thomson Corporation*. Sales offices in New York 17, Detroit, Chicago 1, Los Angeles.

HYDRON METAL BELLOWS — CLIFFORD MANUFACTURING CO. WALTHAM, MASS. — HEAT EXCHANGERS

CLIFFORD HEAT EXCHANGERS
... CUSTOM ENGINEERED
FOR MORE EFFICIENT HEAT TRANSFER

CONSOLIDATED VULTEE AIRCRAFT CORPORATION

San Diego, Calif.

During 1953's 50th Anniversary of Powered Flight, it is fitting that Convair (Consolidated Vultee Aircraft Corporation) assess its own major contributions in the design, development, and manufacture of airplanes because the company also observed an anniversary last May (1953)—its 30th.

To attempt to single out the more outstanding Convair aeronautical achievements of the past 3 decades might be difficult except for the company's pioneering efforts in the field of the delta wing, in hydrodynamic research, and in the realm of turboprop aircraft operations.

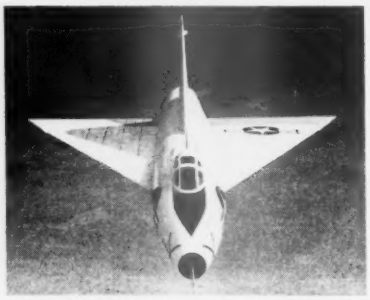
As a result of the design, development, and flight-test program centered around the Air Force XF-92A, world's first delta-wing aircraft, the Air Force has ordered from Convair an undisclosed number of supersonic, delta-wing, jet interceptors, designated the F-102.

Based on the extensive work of the Convair Hydrodynamic Research Laboratory, combined with the knowledge obtained in test-flying the XF-92A, Convair has built and test-flown the Navy XF2Y-1 Sea-Dart, world's first delta-wing seaplane fighter and first combat-type aircraft to utilize hydroskis for improved roughwater take-offs and landings.

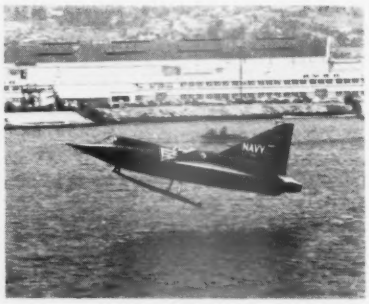
A further outgrowth of the program of the Convair Hydrodynamic Research Laboratory—whose operations with radio-controlled, dynamically similar scale model planes save men, materiel, and money in the determination of the characteristics of full-scale seaplanes before they are ever constructed—came in 1950 with the initial flight of the Navy XP5Y-1, world's first turboprop-powered seaplane. This has been followed by a production contract for the transport version of the XP5Y-1, the turboprop R3Y Tradewind. And 5 years before the P5Y flew, Convair had test-flown the nation's first turboprop plane, the Air Force XP-81 research escort fighter. Also in 1950, Convair flew the nation's first turboprop transport, the Convair-Turboliner and this past summer (1953) contracted with the Air Force to convert two Convair 340 piston-engined transports to Turboliners with installation of Allison T-56 turboprop engines.

In the allotted space, it would be difficult to enumerate all the aeronautical achievements that might be attributed to Convair or its parent companies, Consolidated Aircraft Corporation and Vultee Aircraft, Inc.

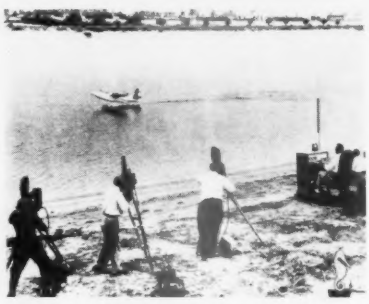
These, however, would find their place in any compilation and are listed here without any particular elaboration as to the background leading up to their ultimate development:



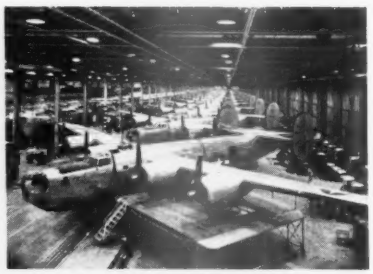
The XF-92A Research Interceptor.



The XF2Y-1 "Sea-Dart."



A one-tenth scale model of the XP5Y-1 in flight controlled by radio by the "pilot" who operates the console on the beach.



The B-24 Liberator Bomber.

The first use of steel tubing in aircraft construction in this country went into the TW-3 trainer, first airplane produced by Consolidated after the company was founded at East Greenwich, R.I., on May 29, 1923.

Convair was the first company to design and install integral wing fuel tanks in any airplane—that is, gasoline tanks located within the wings of large airplanes (first used in PBY Catalina flying boats)—thus providing greater fuel load and increased cargo space.

The company also was the first to receive Army and Navy approval to install a then radically new thermal anti-icing system whereby heated air from heat exchangers in the engine exhaust pipes circulated constantly through metal wing and tail surfaces. Initial use of this principle also was on the PBY Catalinas.

Convair also developed retractable wing-tip floats and incorporated the first ones on PBY's.

The nation's first powered mechanized chain-geared assembly line for producing heavy bombers began operating at San Diego in December, 1941, for turning out B-24 Liberators. The company was also the first to adopt tricycle landing gear in heavy bomber production, first used on the B-24.

Convair was the first company to recognize the advantages of the Davis airfoil, or patented wing design, which provided greater lifting power on take-off and additional speed. The design was first used on the Model 31 flying boat and later on production models of Convair B-24's, C-87's, PB4Y-2's, RY3's, and B-32's.

The company was one of the first, if not the first, in the aviation industry to conduct ram-jet propulsion research. Experimental work and patent applications were filed by Convair on a ram-jet-powered antiaircraft shell early in 1940. The first large-scale ram-jet engine ever flown attained a speed far into the supersonic range in its initial flight at the Naval Ordnance Testing Station, Inyokern, Calif., the flight being an outgrowth of laboratory testing by Convair at the Navy's Ordnance Aerophysics Laboratory, Daingerfield, Tex.

Convair also developed the stainless-steel rivet to provide increased shear strength, pioneered stretched roll shapes of clad sheet aluminum for use as stiffeners in wing skins and spar flanges, and initiated the principle of giving 24ST a second heat-treatment in aging ovens to increase its strength.

The Pratt & Whitney 4360 engine was first flown in the Vultee V-72 Vengeance dive bomber. The first plane flown that was designed to incorporate the P&W 4360 engine was the Vultee XA-41 attack plane; subsequently, the Convair B-36, the Boeing C-97, and other production planes were designed to incorporate this same engine.

Convair was the first aircraft company to adopt a master tooling dock for manufacturing jigs and fixtures with speed, accuracy, and economy, as well as the first in the industry to utilize

Remote electrical control opens or closes this new Fuel Shut-Off Valve in one second. Actuated by pump pressure, it provides high flow rate with low pressure drop by use of a single poppet fastened to a flexible Teflon diaphragm. Specifically designed for turbojet engine afterburner and rocket fuel feed systems, the valve is normally installed downstream from the pump. It has no close-fitting parts — handles unfiltered fuel acceptable to the pump. Aromatics in aircraft fuels do not affect the parts, and most rocket fuels do not corrode them.

In operation, fuel at pump pressure enters a chamber above the valve diaphragm through a filtered inlet bleed passage. Connecting the chamber to the downstream side of the diaphragm is an outlet bleed passage which closes when a solenoid is de-energized. Thus fuel pressure in the chamber holds the valve member in closed position. Energizing the solenoid reverses the action — holds the valve open. DC power failure closes the valve — operation is fail-safe. If desired, an alternate configuration provides for *opening* the valve should power fail.

Integral legs permit mounting to the structure and allow adequate work area for attaching piping flanges.

SPECIFICATIONS: Type 141 RL8 Fuel Shuit-Off Valve

RATED FLOW: 12,000 lbs./hr. at 15 psi drop. Valve size may be scaled for larger or smaller flow rates, as required. **PRESSURE:** 600 psi maximum. **OPERATING PRESSURE:** 2.5 psi minimum. **OPERATING SPEED:** 1 second opening; 1 second closing. **TEMPERATURE:** Minus 65° F. to plus 300° F. **POWER SUPPLY:** 17-30 volts DC, 1 ampere maximum. **MATERIALS:** Housing: Aluminum alloy. Diaphragm and Seals. Teflon. Valve Members and all other parts: Stainless steel. **CONNECTOR:** AN3102A-10SL-4P. **PIPE CONNECTIONS:** AND10086-20 flange fittings. **OVERALL DIMENSIONS:** Height 4-21/32″. Width 6-11/32″. Length 5-13/32″. **WEIGHT:** 3-1/2 lbs.

MANNING, MAXWELL & MOORE, INC.

AIRCRAFT PRODUCTS DIVISION • STRATFORD, CONN. • INGLEWOOD, CALIF.

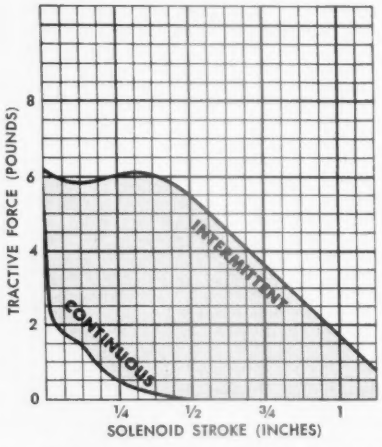
OUR AIRCRAFT PRODUCTS INCLUDE: TURBOJET ENGINE TEMPERATURE CONTROL AMPLIFIERS • ELECTRONIC AMPLIFIERS PRESSURE SWITCHES FOR ROCKETS, JET ENGINE AND AIRFRAME APPLICATIONS • PRESSURE GAUGES THERMOCOUPLES • HYDRAULIC VALVES • JET ENGINE AFTERBURNER CONTROL SYSTEMS.

Terminals are hermetically sealed by exclusive process developed for Cannon's widely acclaimed hermetically sealed electric connectors.
Insulation test: 1000v ac
The armature (plunger) and the anvil are high quality annealed Armco magnetic ingot iron.
Molded Nylon cap protects the terminals.
Molded "Silcan" cap protects the return spring and plunger end.
Silver brazed seals

TRUE
hermetic sealing in this new

CANNON *dc* SOLENOID

For pressurized or corrosion resistant service, Cannon's dc Solenoids offer positive hermetic sealing, sound construction, painstaking workmanship and highest quality materials. A vitreous insulating material is heat-fused to shell and contact terminals, creating a perfect seal. Other parts are silver brazed. The entire solenoid is then copper-nickel-chrome plated to insure complete coverage, high corrosion resistance and long, trouble-free service. Solenoid No. 19760, above, the first hermetically sealed product of this type, is built for continuous duty on 28v dc systems. Fitted with other coils, it renders intermittent duty as characterized by the chart at right. Cannon's hermetically sealed solenoid series reflects the same uncompromising attention to details of sound design, engineering and workmanship that has made the name "Cannon" synonymous with "quality" for more than 38 years. For complete information write for new Solenoid Bulletin DCS4-1953 showing 105 different assemblies.



Solenoids of the hermetically sealed 19760 series, through modification of the coil windings, can meet various characteristics and specific applications within the limits indicated above.

CANNON ELECTRIC
Since 1915
CANNON ELECTRIC

CANNON ELECTRIC COMPANY, LOS ANGELES 31, CALIFORNIA
Factories in Los Angeles, Toronto, New Haven. • Representatives in principal cities. Address inquiries to Cannon Electric Company, Dept. L 105, Los Angeles 31, California.

human measurements in designing jigs and fixtures to raise production efficiency by providing adequate working space for employees.

Convair designed, developed, and produced the world's largest bomber, the Air Force B-36; its troop-and-cargo counterpart, the Air Force XC-99, world's largest land plane; and the first military plane designed and built especially for training Air Force navigators and bombardiers in groups, the T-29 "Flying Classroom."

And the company was the first awarded an Air Force contract to build the air frame for the world's first atom-powered aircraft.

CONTINENTAL MOTORS CORPORATION

Detroit, Mich.

At the time of the Lindbergh flight in 1927, Continental Motors was the largest independent manufacturer of automotive-type engines in the world. Because of the large number of surplus aircraft engines available for years at prices that no manufacturer could meet competitively and also because there had been no assurance of a sufficiently large market to warrant expenditure of the considerable sum required to develop a new airplane engine, the Continental management had refrained from entering the aviation field. However, with public interest in flying growing by leaps and bounds, Continental's directors decided to bring out a line of airplane engines. A survey indicated the desire of leading airplane manufacturers for a more powerful engine than the old 90-hp. Curtiss OX-5, so it was decided to build first a conventional seven-cylinder radial air-cooled engine that would develop approximately 160 hp. Work commenced in October, 1928, and the first engine was ready for its first test run 6 months later. This engine, named the A-70, received its Approved Type Certificate in October, 1929, with a rating of 166 hp., just a year after work on it had started.

Work had also been going forward quietly in Continental's research department on a small engine of an entirely new type for the single- and two-place planes with which several manufacturers were experimenting. This project eventually became Continental's greatest achievement in the aviation engine field and its most important contribution to the industry. The small engine was so compact, so economical to produce, and so popular that it was widely copied. Today, engines of this type have virtually replaced radial engines in the light-plane field and are being built over a wide range of horsepower. Its Approved Type Cer-

CABIN COMFORT

To give passengers cool comfort in hot summer weather, forward-looking airlines are modernizing their cabin pressurization and air conditioning equipment by installing Stratos high capacity cabin superchargers and refrigeration units.

Capable of handling the requirements of high density aircraft, Stratos units are replacing older equipment in Constellations and Convairs and have been ordered in quantity by the Air Force.

Stratos superchargers and air cycle units assure the airline operator the most for his air conditioning dollar. They have established outstanding service records. The highly efficient Model B-60 Bootstrap cooling unit illustrated below, for example, has a specified overhaul period of 2500 hours.

MODEL B60 REFRIGERATION UNIT

Axial flow turbine • Rated Flow 62 lbs/min. • Discharge temperature, approximately 0°F. on 100° day

FOR MORE INFORMATION WRITE:

STRATOS

A DIVISION OF FAIRCHILD ENGINE & AIRPLANE CORPORATION

Main Office and Plant: Bay Shore, Long Island, N. Y.
West Coast Office: 1355 Westwood Blvd., Los Angeles 24, Calif.

•

OTHER STRATOS PRODUCTS

Air-Turbine Drives • Cabin Superchargers • Air Cycle Refrigeration Equipment
Air Moisture Separators • Mass Flow Valves • Emergency Disconnects

tificate was received in May, 1931. This engine was named the A-40 because it was to develop about 40 hp. Actually, it was rated at 38 hp. at 2,800 r.p.m. It was a four-cylinder, L-head, four-cycle design, with the cylinders cast in pairs and mounted horizontally on opposite sides of the crankcase. Its frontal area was small, and its overall shape lent itself to effective streamlining for speed and provided for greater forward vision for the pilot. Its weight was 138 lbs. with magneto and carburetor.

Looking back, it is clearly evident that Continental's original A-40 became one of the cornerstones of the industry. It provided, for the first time, an engine of outstanding reliability which could be built at a price calculated to stimulate the sale of planes to private users.

Today, the company builds a broad line of four- and six-cylinder models of this type, ranging from 65 to 225 hp., in addition to the seven-cylinder radial model. Its subsidiary, Continental Aviation & Engineering Corporation, builds a nine-cylinder 550-hp. radial, the R-975, for plane and helicopter use. Continental recently purchased U.S. rights to several models in the Turbomeca family of gas-turbine power plants, developed by the Society Turbomeca of Bordes, France, in collaboration with the French Air Ministry, and has licensed its subsidiary to build them. One model is already in production, and plants are under way in Muskegon and Detroit to handle the substantial volume of orders already booked.

COOPER PRECISION PRODUCTS

Los Angeles, Calif.

"For the want of a nail a kingdom was lost" emphasized the importance of fasteners many years ago, and fasteners have continued to be of vital importance in our lives and in many industries up until the present time.

With the advent of jet-propelled aircraft, it became apparent that the standard aircraft fasteners were wholly inadequate to hold together the assemblies of airplanes that at fantastic speeds were developing terrifically high temperatures and enormous stresses.

Harry S. Cooper, being intrigued by the problems found in the field of aircraft fasteners, came out of retirement 5 years ago to organize Cooper Precision Products in Los Angeles, where he built a factory and equipped it with new and modern machinery for the production of aircraft bolts by both cold-heading and hot-heading methods.

Mr. Cooper surrounded himself with men of many years experience in this particular field and started manufacturing a full line of standard aircraft bolts and specialized in close tolerance, high tensile, high temperature, and bolts of special design and special alloys.

The engineers of all of the air-frame and engine manufacturers were invited to make use of these facilities, and this has provided Mr. Cooper with many opportunities to contribute to the development of bolts manufactured from materials that have previously been considered too difficult to work by cold-heading methods.

Cooper Precision Products has manufactured bolts from many of the stainless-steels alloys, as well as from "K" Monel, Inconel "X," and 19-9 DX, and has carried on extensive experiments on other alloys that may, in the future, be found suitable to overcome weight and heat factors being encountered in present designs.

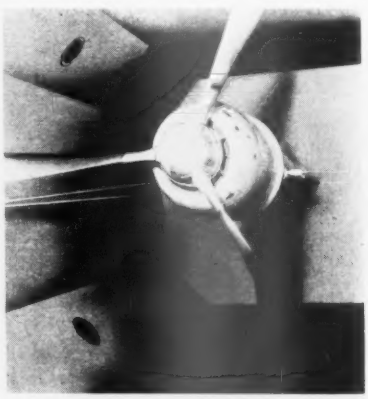
CORNELL AERONAUTICAL LABORATORY, INC.

Buffalo, N.Y.

The 50th Anniversary of Powered Flight, 1953, marks the 10th year of aeronautical research and development at Cornell Aeronautical Laboratory, Inc., in Buffalo, one time Curtiss-Wright Research Laboratory. Many accomplishments over this period could be cited, including the few that follow.

In aircraft design, efforts yielding important basic design data have included analyses of structural tail loads, low aspect ratio wings, wing-body interference, and various aeroelastic and flutter phenomena.

Research on three major guided-missile programs has led to propulsion and guidance advances, included important first flights of a supersonic ram-jet and a roll-controlled rocket, as well as development of a high-frequency transfer valve now common to most missile servo systems.



Cornell Laboratory's 2,000-hp. propeller dynamometer is now in regular research and testing service. It provides for single- or double-shaft model propellers of 4- to 5-ft. diameter and supersonic tip speeds. Thrust, torque, and speed of each shaft are measured by precision electrical equipment.

A pioneer in full-scale flight research, the Laboratory enjoys an international reputation in stability and control research and is the first to have successfully performed a stalled glide.

Safety research has ranged from practical engineering developments for the alleviation of the effects of crashes to complex operations analysis.

Research in materials has unveiled lean alloys for high-temperature use and lightweight plastic sandwich structures.

Efforts in electronics and instrumentation have included some of the earliest developments in radio and television telemetering, which provide instant reception on the ground of flight-test data.

The most recent achievements at Cornell Aeronautical Laboratory include a successful large-scale transonic throat of new design and a hypersonic impulse tunnel that attains speeds 13 times that of sound.

CURTISS-WRIGHT CORPORATION

Wood-Ridge, N.J.

The pace in aeronautical development during the last few years has brought about an almost complete change of the rules. Where powerplant development, for example, once strolled along at the rate of about 100 hp. per year, the increments in power now are at annual rates that are astronomical by comparison.

Today, engines are powering planes that fly faster than sound and guided missiles at rates that outspeed the sun. These are the culmination of the first half-century of flight and the bellwether of the future.

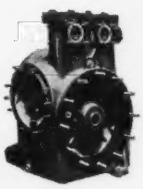
Looming large both in the past and in the preview of the future of aviation is the Curtiss-Wright Corporation.

It is a company that has been gifted with the initial experiences and successes of its forebears—the brothers Orville and Wilbur Wright, and Glenn H. Curtiss, inventor-flier. A leader over the years, the organization built the first successful radial air-cooled engine in the United States; it was the first to achieve 1,000 hp. in an aircraft engine; the first to attain the ratio of 1 hp. per pound of weight for a mass-produced aircraft engine, and the first to design an engine that delivered 1 hp. for less than a cubic inch of piston displacement. The culmination of this is the 18-cylinder Turbo Compound, now rated at more than 3,500 hp. This engine, which has been described as the most efficient power plant ever built for

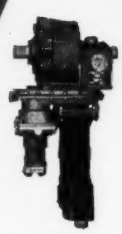
gearing for the *Age of Flight*

WESTERN GEAR WORKS

Designing, manufacturing, testing and producing in quantity — one or thousands — of specialized gear drives for the Aviation Industry has been a major activity at Western Gear since the first days of mechanized aircraft. Western Gear aircraft engineers are available to work with you to efficiently and effectively solve your mechanical power transmission problems. Call on us now — no obligation.



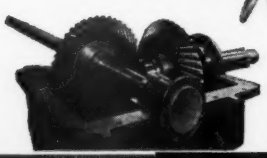
Turbine powered auxiliary power unit is shown. Western Gear has designed and built many gear drives for use with gas turbines.



Actuators . . . illustrated is a special dual powered rotary actuator using both hydraulic and electric motors. Thousands of different types of specialized actuators have come from Western Gear drawing boards.

Avionics . . . Electronics in Aviation . . . electronic equipment manufacturers use Western Gears for many kinds of airborne equipment. Fine pitch differential shown was used on electronic equipment aboard guided missile.

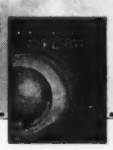
Power-On Scale Models . . . illustrated is a Western Gear designed and built scale model of counter rotation unit for power-on wind tunnel testing.



Illustrated is a Western Gear main power drive for a wind tunnel. Many standard and special gear drives are available for laboratory, research and other aviation industry experimental projects.

5329

DID YOU GET YOUR COPY OF GEARING FOR THE AGE OF FLIGHT? Use the convenient coupon below to obtain this important brochure.



WESTERN GEAR WORKS

Manufacturers of **PACIFIC-WESTERN** Gear Products

Pacific Gear & Tool Works

Plants: Seattle
San Francisco
Belmont (S. F. Peninsula)
Lynwood (Los Angeles County)
Pasadena
Houston

Write, wire or phone your nearest Pacific-Western office

Plants—417 Ninth Ave. S., Seattle 4, Washington
2800 E. Imperial Highway, Lynwood (Los Angeles County), California
1035 Folsom St., San Francisco 3, California
Belmont (San Francisco Peninsula), California
132-134 W. Colorado St., Pasadena 1, California
117 N. Palmer St., Houston 3, Texas

Representatives—N. 2605 Division St., Spokane, Washington
930 S. E. Oak St., Portland 14, Oregon
Room 212, Ross Bldg., Denver 2, Colorado
500 South Ervay Street, Dallas, Texas
Engineering & Machinery Ltd., 1366 W. Broadway, Vancouver, B. C.

WESTERN GEAR WORKS
Executive Offices, Post Office Box 182, Lynwood, California

Please send booklet No. 5201
"GEARING FOR THE AGE OF FLIGHT"

NAME_____
COMPANY_____
TITLE_____
ADDRESS_____
CITY_____ ZONE____ STATE_____

DEPARTMENT OF TECHNOLOGY
BUFFALO PUBLIC LIBRARY

aircraft, has been selected by 22 leading world air lines to power fleets of Douglas DC-7 and Lockheed Super Constellation transports.

The products of Curtiss-Wright have constantly been in the public eye. The Hispano-Suiza, known popularly as the Hisso, was a premier engine in the first World War. Shortly after the Armistice, the Curtiss JN4-H, powered with four Hissos, completed the first successful mass transcontinental flight without a single forced landing.

In the decade of the 1920's Wright-built engines made possible the historic flights of Byrd, Kingsford-Smith, Lindbergh, Amelia Earhart, and many others. This was the time when the company began producing Whirlwind and Cyclone engines. In the next 10 years the Cyclone 9 was the engine with which the air lines extended their routes throughout the United States and overseas. An advanced model of this—the G-100—was the first engine of its type to reach 1,000 hp. and to achieve the magic formula, shortly after, of 1 hp. for each pound of weight.

Before the end of the 1930's Curtiss-Wright engineers had developed a new 18-cylinder Cyclone that yielded 2,000 hp., 500 more than a Cyclone 14, which previously had held the highest power rating ever given to an air-cooled radial in this country by the Civil Aeronautics Authority.

First installed in a Consolidated flying boat, two of these 18-cylinder units easily lifted the 50,000-lb. plane from the water on its maiden flight.

To date, Wright Cyclone 18-cylinder power plants have been operated for more than 40 billion engine-miles.

In World War II it was Curtiss-Wright Warhawks, Kittyhawks, Tomahawks, Helldivers, and Commandos. In more than 100 types of military aircraft the Wright Whirlwind and Cyclone engines powered the air might of the United States, with the culmination being the two premier bombardment airplanes—the B-17, scourge of the enemy in Europe, and the B-29, conqueror and leveller of Japan's industrial and military might as the carrier of the first atom bomb.

In such champion airplanes as the Republic Thunderbolt, the Consolidated PB2Y-2, the Martin B-26, and the Bel Airacobra is told the success story of the first successful controllable-pitch propeller in the world from the Curtiss-Wright Propeller Division.

The Korean conflict once again proved the worth of the Wright-powered B-29, where it was called upon to be the decisive factor in subduing and making ineffectual the vital supply line and troop movement activities of the enemy. Bomber groups of the Air Force's Far East Command operated B-29's close to 97 per cent of the total days spent in the tactical operation.

Present-day thinking of Curtiss-Wright aeronautical engineers envision power plants that develop the equivalent of 15,000 or 20,000 hp. or even more, and active research fields at Wright Aeronautical, engine component of the corporation, encompass all the complex problems accompanying increased engine power. In the piston-engine field, where the Wright Turbo Compound is the most efficient ever built, development is being carried well beyond the 3,500-hp. mark.

The Turbo Compound has been in production since the latter part of 1949 and is being procured by the military services in large quantities for the U.S. Navy's P2V, P5M, R7V, and WV2, the USAF's C119H and RC121, as well as by 22 leading air lines to date for their Super Constellation and Douglas DC-7 transports.

This division has kept pace with jet-engine development and production. The Wright J65 turbojet, capable of more than 7,200 lbs. thrust, is now powering the Air Force's F-84F fighter, the B-57 twin-engined medium bomber, and the Navy's FJ-3 and is the scheduled power plant for other military aircraft. The Wright J67 turbojet will be installed in future military aircraft and is being strongly considered as one of the power plants for the coming American-made commercial jet transports.

In the aerodynamic and thermodynamic spheres Wright engineers are studying and developing new techniques for supersonic inlets and nozzles for ramjet, turbojet, and turboprop engines; turbojet and turboprop compressors and turbines for all speeds; combustion, blade cooling, anti-icing, and other heat-transfer problems; engine passages; aero-thermo consultation on component design of engines; and new type engines.

Developmental work on Wright turbojets J65 and J67, Turbo Compound piston engines, turboprops, and a wide variety of Cyclone 7-, 9-, and 18-cylinder power plants is also continuing.

New materials and processes are coming in for their share of research and development phases at Wright Aeronautical. They include: compressor and turbine blade fabrication techniques; nonstrategic heat-resistant alloys; titanium; molybdenum; ceramic coatings; powder metallurgy research; welding development for jet engines; and high-temperature brazing development.

A new turboprop engine and an advanced series of propellers to provide long-range military aircraft with propeller-driven controllability and fuel economy at jet speeds have been developed at the Wright Aeronautical and Propeller divisions. The new turboprop engine is expected to dwarf in power any aircraft engine yet made public.

The new propellers, designated the Turboelectric series, are capable of harnessing power outputs up to 20,000 hp. and more and will, it is anticipated, pave the way for the eventual attainment of speeds up to 1,000 m.p.h.

Produced by the company's Propeller Division, the Turboelectrics have been selected to equip a majority of the types of turbine-powered, propeller-driven aircraft now being built in this country.

Already in production are Curtiss-Wright propellers for the YC-124B, a turboprop version of Douglas' giant Globemaster, and the C-130 built by Lockheed and the first aircraft to be designed from the beginning as a turboprop transport.

Included in the Turbolectric series are models designed for use with each of the high-powered military turboprop engines currently slated for production in the U.S.

Some models of the Curtiss-Wright turboprop propellers range up to almost 20 ft. in diameter. They are of the three- and four-bladed single-rotation, and the six- and eight-bladed dual-rotation, types. Blades are hollow-steel, produced by a new extrusion process perfected by Curtiss-Wright in cooperation with the U.S. Air Force.

The Propeller Division's rocket-engine facilities continue to provide the Air Force with new developments in this field.

The Electronics Division of the Curtiss-Wright Corporation, pioneer in the aircraft simulator field and the only producer of such equipment to deliver units to the USAF, Navy, and commercial operators, has a long-term program that will add both new training aids and new types of electronic equipment to its product line.

Continuing development on aircraft simulators and duplicators is also being pursued. A new radio aids attachment is now available for pilot and crew training, for example, and all-electronic control loading has been developed as a replacement for the earlier systems. In addition, new designs for computer and power supply cabinets are making possible greater ease in installation and maintenance.

The introduction of the Curtiss-Wright Dehmel Simulators and Duplicators has caused a major change in flight-training techniques. Today, for the first time, complete aircrews are able to train together. Moreover, they are able to try out on the ground, and in perfect safety, many emergencies that would be far too dangerous to try in the air.

CHARACTER....

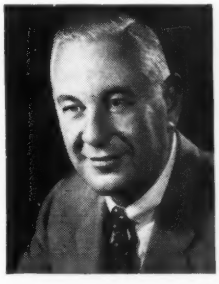
AIR ASSOCIATES, INC.

"The Sign of Better Equipment"

Reputation can be acquired . . . often overnight . . .
and it can be destroyed entirely in the same space of time . . . but character is that priceless thing . . .
built not bought . . . it endures. It evolves slowly through the years out of rich
achievement and fine works. More than a stamp of approval, character is time's acceptance.
The character of Air Associates has been emphasized by the more than a quarter century of service to Aviation.
Today, the insignia proudly illustrated,
identifies the seller of products . . . designed, produced, and distributed by our company . . .
as the best regardless of price. When you display this sign you attract the cream of Aviation equipment buyers.
When they purchase they do so with complete confidence in the quality of the product and
the character of the company.

"DO MORE BUSINESS . . . MAKE MORE PROFIT WITH AIR ASSOCIATES' EQUIPMENT."

J. E. Ashman
PRESIDENT



AIR ASSOCIATES, INC.

HOME OFFICE • TETERBORO, N. J

DIVISIONS: ATLANTA • CHICAGO • DALLAS • GLENDALE • HACKENSACK • MIAMI • ORANGE • TETERBORO

Simulators, as developed by Curtiss-Wright, are actual plane cockpits in which the normal movements of instruments and controls have been replaced with identical electronic impulses. Accurate effects, including engine and propeller sounds, and the proper fashion in which controls and gages reflect varying conditions of simulated flight give aircrews a sense of complete flight realism, although the Simulator never moves or leaves the ground.

Air emergencies—mechanical or radio failures, the formation of wing ice, and the like—are created with a trouble console instrument panel, which the instructor uses whenever he wants to add problems to a training flight.

To date the Electronics Division has built Simulators for the following aircraft: Boeing Stratocruiser passenger transport, B-50 bomber, F2H Banshee jet fighter, Fairchild Packet, Douglas C-124 Globemaster, Convair B-36 bomber, and Boeing C-97 military transport. The Division currently is at work on Simulators for the Convair 340, Douglas DC-6B, and the B-52 eight-jet bomber.

Whereas Simulators are exact copies of airplanes, the Duplicators manufactured by this division of Curtiss-Wright are general-purpose units with a single-seat cockpit containing basic flight controls, instruments, and radio equipment.

The more power that is obtained in an aircraft engine, the more complex become the problems in adjacent fields. Metallurgy comes in for its share. Foreseeing this, Curtiss-Wright established its Metals Processing Division at Buffalo, N.Y. This component of the corporation has an active development program in force to bring about production techniques that will result in greater precision and lesser costs in the field of forgings, castings, extrusions, and the like. Its facilities are geared to the manufacture of the various types of blades that make up integral parts of the tubojet and turboprop engines of the corporation.

At present, the Curtiss-Wright Corporation has ten divisions and subsidiaries. It employs approximately 30,000 people.

Other divisions and subsidiaries of the company include the Caldwell-Wright Airport, which operates a completely equipped shop for the maintenance and overhaul of aircraft engines. In addition, ten test aircraft ranging from single-engined planes to multiengined bombers are housed at the airport, where the majority of the test and development work for the Turbo Compound, J65 turbojet, turboprop engines, turboelectric, and extruded blade propellers are carried out in the various aircraft under flight conditions.

The Marquette Metal Products subsidiary, Cleveland, Ohio, produces precision clutches, diesel governors, electric windshield wipers for all-type aircraft, rotary-type reversible oil pumps, and textile spindles.

Columbia Protektosite, subsidiary, manufactures nylon bearings, molded nylon gears, extruded tubing, and a consumer line of household and personal plastic articles.

Contracts for the sales and servicing of Curtiss-Wright products outside the United States are a function of the Export Division.

The Specialties Division develops additional earning power for the corporation's products through the licensing or sale of such proprietary rights, patents, designs, and similar rights as Curtiss-Wright may now, or in the future, own or control.

Formation of the tenth unit, Curtiss-Wright Europa, N.V., with headquarters in Amsterdam in The Netherlands was announced recently. This organization was formed as a result of the many Curtiss-Wright products being made available to NATO nations.

DOAK AIRCRAFT COMPANY, INC.

Torrance, Calif.

In 1939, with war already on in Europe, Edmond R. Doak foresaw the metal shortage and the desirability of using a more plentiful material. He resigned as Vice-President of Douglas Aircraft Company, Inc., and General Manager of its El Segundo Division to form his own company in Hermosa Beach, Calif. There he designed and built a molded plywood military training plane.

When procurement of other aircraft ended the need for a plywood plane, Doak formed a wood aircraft parts division with the large furniture firm, Kroehler Manufacturing Company. In four of Kroehler's eight plants, approximately 1,800 workers built aircraft parts converted to wood by the design group of Doak Aircraft. This continued under Doak's management until the metal shortage lessened.

In the meantime, Doak Aircraft was transforming an ancient glass factory in Torrance, Calif., into a modern metal-working aircraft plant. Floor area was expanded to 170,000 sq. ft., with 1,500 employees and facilities for complete manufacture and processing of wings, bomb-bay doors, flaps, empennage assemblies, tanks, and fuselage sections.

Following the war, in addition to aircraft parts, Doak made metal furniture, display equipment, and other domestic items until the outbreak of the Korean conflict. Then the company again devoted its entire attention to aircraft.

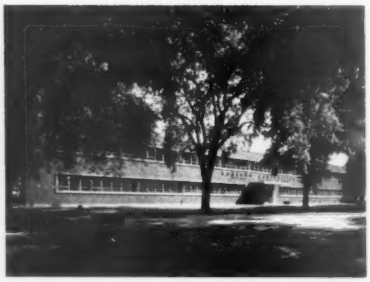
Meanwhile, recognizing the tremendous future for vertical lift type aircraft, Doak maintains a continuing program of research and development in this field.

DOELCAM CORPORATION

Boston, Mass.

Doelcam Corporation announces completion of its new plant in Boston, Mass., to be devoted primarily to large-scale production of synchros, gyroscopes, servomotors, and similar electrome chanical devices for precision instrumentation systems.

The Company also reports the opening of a West Coast office in Palos Verdes, adjacent to many of the nation's aircraft manufacturers.



The new plant of Doelcam Corporation.

The facilities of this firm in Newton, Mass., have been retained for the use of its expanded Engineering and Research and Development Departments. The Model Shop, Mechanical and Electrical Laboratories will remain at the Newton plant, and the manufacture of certain subassemblies will continue at that location.

DOUGLAS AIRCRAFT COMPANY, INC.

Santa Monica, Calif.

During 32 years of operation under the same management, Douglas Aircraft Company, Inc., has made a number of significant contributions to the advancement of aviation and the aeronautical sciences. Since their final evaluation must await the judgment of future historians, the more important Douglas engineering developments will be presented in chronological sequence.

Two forward steps were represented in the "Cloudster," first airplane to be produced by Donald W. Douglas. It was the first biplane of its size and weight to employ a single-bay wing arrangement, and it established an American precedent in 1922 by lifting a useful load equal to its own empty weight.

NEW DISCOVERY IN INSTRUMENTATION

(reading time • 15 seconds)

Yesterday

Directional Gyro — Torquer, Cager, Pickoff + Rate Gyro — Pickoff, Damper + Mixing Circuitry = $\theta+\dot{\theta}$

TODAY..

$=\theta+\dot{\theta}$

	Reliability	Drift	Current	Weight	Cost
yesterday	.950	.5 /Min	3 amps	12 lbs.	
today	.999	.1/Min	.3 amps	3 lbs.	

SUMMERS
GYROSCOPE
COMPANY
2328 BROADWAY • SANTA MONICA, CALIFORNIA

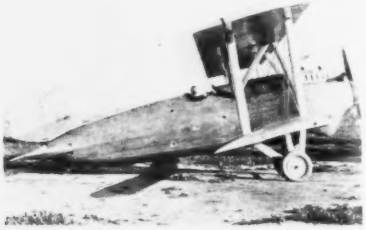
(Top) Douglas Skyrocket. *(Bottom)* Douglas DC-7.

The "Cloudster" also foreshadowed the basic Douglas philosophy of building "practical" airplanes—i.e., airplanes that are as sound economically as they are structurally and aerodynamically.

Only 2 years after the flight of the first Douglas airplane, the "World Cruisers," produced by the same company, played a stellar role in the historic first flight around the world. This accomplishment by pilots of the U.S. Air Service not only furthered the progress of flight but raised the prestige of American aviation to a pinnacle from which it has not been dislodged.

The promise of long-range air travel made by the "World Cruisers" was more than fulfilled by introduction of the "DC" (Douglas Commercial) series of transports in 1933. For speed, power, comfort, and dependability the DC-1 surpassed anything in the air. Further improvements, made after successful tests, resulted in production models designated DC-2. The first DC-2 was flown in 1934, and some remained in useful service until early 1953.

The excellent showing of the DC-2 in the 1934 Robertson Air Race had a profound influence on commercial aviation around the world. The Douglas transport, significantly carrying a full pay load, placed second to a specially built English racing plane.



Cloudster.

A larger and better power plant and a wider fuselage were the principal improvements on the succeeding DC-3, probably the best known and most widely flown airplane ever built. Because of its combination of speed, range, and pay load, the DC-3 completely dominated the field of commercial air transports until 1946. Nearly 11,000 aircraft of the DC-3 series, including military configurations, were produced by Douglas.

In the field of carrier-borne aircraft, design success of the SBD Dauntless attack bombers in 1940 was carried through with the AD-Skyraider series of versatile single-engined attack planes. Soon to follow are the twin-jet-powered A3D attack bomber and the fast F4D Skyray interceptor, which has a modified delta wing.

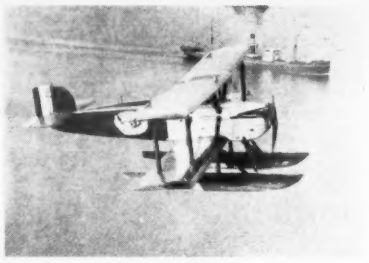
While the DC-3 was at the zenith of commercial utility, Douglas undertook a major development project for the Air Force by designing and building the XB-19. This aerial behemoth, which pioneered the field of large bombers, first flew on June 27, 1941. Until it was scrapped in 1949, the B-19 served as a flying laboratory, which proved structural design, as well as tested power plants, propellers, and electronic systems for succeeding production of heavy bombers.

Next in the "DC" series, the DC-4, made its major contribution while in military service as the C-54. In performing logistic miracles, this four-engined transport firmly established the practicability of transoceanic travel by land-based aircraft. The DC-6 and DC-7 series of air liners, developed from the same basic design, have proved to be able successors in the commercial field, while the C-124 Globemaster now provides the bulk of long-range transport for the military.

Important aeronautical knowledge has been derived from two recent high-speed research aircraft developed by Douglas for the Navy. The D-558 Skystreak explored transonic phenomena with a straight-wing design, and the D-558-2 Skyrocket continued the research program with swept wings.

Coincidentally, the Skystreak established two successive official speed records during August, 1947—one of 640.7 m.p.h. and the other of 650.5 m.p.h. The Skyrocket, dropped from a mother plane, used its rocket power alone to attain an altitude of 79,494 ft. and a speed of 1,238 m.p.h. during two flights in August, 1951.

Specific contributions made by a third Douglas high-speed research airplane, the Air Force X-3, still are classified information. The X-3 was first flown on October 20, 1952.

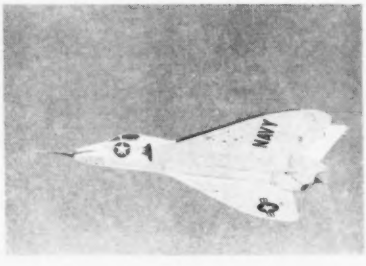


World Cruiser.

DC-2.

AD-5.

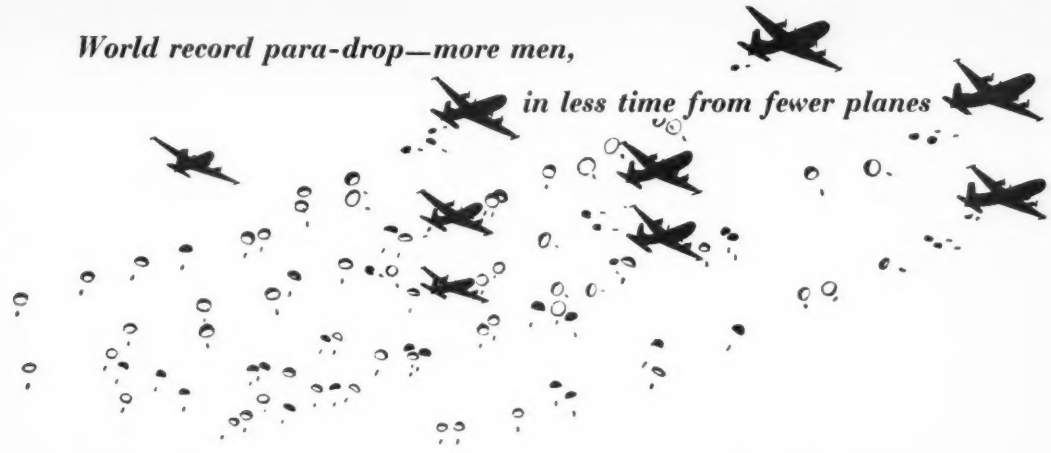
A3D.



F4D.

World record para-drop—more men,

in less time from fewer planes



with the—**Douglas C-124 Globemaster**

Nine Douglas C-124 Globemasters of the 18th Air Force, 62nd Group, 7th Squadron, cruised above Fort Bragg. Seconds later, more than a thousand paratroopers had hit the silk... were floating down on the drop zone.

For this record-breaking drop, Globemaster—the Air Force's largest operational transport plane—was a logical choice. Clamshell doors, located in the nose, make loading of troops or matériel fast and easy. Load space is two stories high... gross weight at take-off, 87½ tons. A single Globemaster can transport 200 armed troops across the Atlantic—deliver 25-ton loads of tanks, cranes, loaded trucks to fill immediate needs at bases anywhere in the world.

Performance of the C-124 Globemaster is another example of Douglas leadership in aviation. Planes that can be produced in quantity to fly *faster and farther with a bigger payload* is a basic rule of Douglas design.

Enlist to fly in the U. S. Air Force

Depend on *DOUGLAS* **First in Aviation**

THE DOW CHEMICAL COMPANY

Midland, Mich.

Magnesium's greatest contributions to powered flight have occurred in the last decade. It is significant that with only a 10-year history, magnesium is being used in quantity on production aircraft not only in secondary structures but also in primary structural applications. New developments are expected to increase production usage.

Basically, magnesium is used in aircraft because of its light weight combined with good strength. The present trend in aircraft toward greater gross weights as dictated by tactical requirements has necessitated the reduction of air-frame and power-plant weight, wherever possible, through the use of magnesium.

Aircraft utilizing large amounts of magnesium sheet and extrusions in primary and secondary air-frame structures include the B-36 with its almost 9,000 lbs. of magnesium mill products in the air frame alone; the F-7U1 using more than a ton of magnesium, 1,813 lbs. of which is magnesium sheet; the C-124 with magnesium floor beams; the S-55 helicopter, in which almost all of the entire contour skin is magnesium sheet; and the B-47, with significant amounts of sheet and extrusions.

The recent development of improved high-strength sheet and extrusion alloys is expected to result in still greater usage of magnesium in air-frame structures.

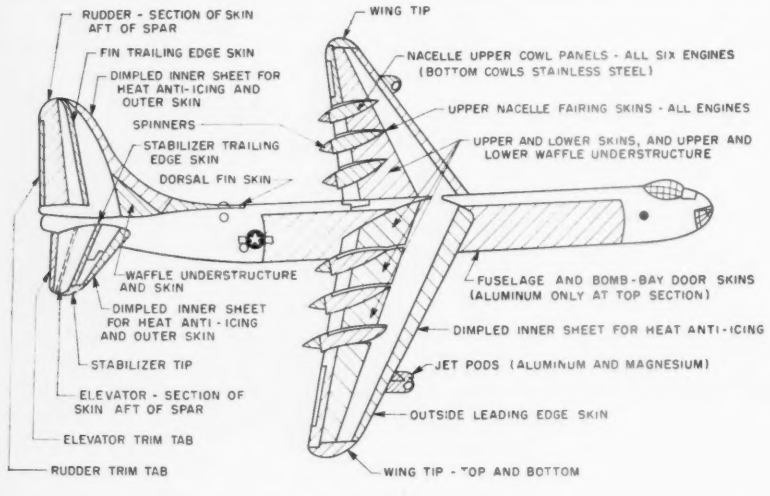
Generally speaking, all current jet and reciprocating engines utilize substantial amounts of magnesium castings. The development of the magnesium-rare earth alloys several years ago extended the temperature range in which magnesium alloys can operate, and the still-newer magnesium alloys containing thorium have pushed the upper temperature limit still higher. It has been said that the magnesium-thorium alloys, combined with the magnesium-rare earth alloys, constitute the most significant advance in jet-engine metallurgy in the last few years. These new casting alloys possess good strength characteristics at temperatures ranging as high as 650°.

Closely paralleling the development of these elevated temperature magnesium casting alloys has been the development of high-strength elevated temperature wrought alloys. All of the developments have extended the usable range in which light metals can be used in high-speed aerodynamically heated aircraft.

Production models of guided missiles are utilizing high percentages of both cast and wrought magnesium products.

Military aircraft applications have paved the way for successful adaptation of magnesium to commercial aircraft. Most notable is the use of magnesium floor beams in the DC-6 series and DC-7 air frame and the use of magnesium floor beams and extruded flooring in the newest Super Constellation.

Sand-cast magnesium wheels have been standard on most aircraft for a number of years. At the present time magnesium forged wheels are being tested. Results so far indicate that the forged wheels will appreciably increase service life and allowable loading as compared with cast designs.


RUDDER - SECTION OF SKIN AFT OF SPAR
FIN TRAILING EDGE SKIN
DIMPLED INNER SHEET FOR HEAT ANTI-ICING AND OUTER SKIN
SPINNERS
STABILIZER TRAILING EDGE SKIN
DORSAL FIN SKIN
WAFFLE UNDERSTRUCTURE AND SKIN
DIMPLED INNER SHEET FOR HEAT ANTI-ICING AND OUTER SKIN
STABILIZER TIP
ELEVATOR - SECTION OF SKIN AFT OF SPAR
ELEVATOR TRIM TAB
RUDDER TRIM TAB
WING TIP
NACELLE UPPER COWL PANELS - ALL SIX ENGINES (BOTTOM COWLS STAINLESS STEEL)
UPPER NACELLE FAIRING SKINS - ALL ENGINES
UPPER AND LOWER SKINS, AND UPPER AND LOWER WAFFLE UNDERSTRUCTURE
FUSELAGE AND BOMB-BAY DOOR SKINS (ALUMINUM ONLY AT TOP SECTION)
DIMPLED INNER SHEET FOR HEAT ANTI-ICING
JET PODS (ALUMINUM AND MAGNESIUM)
OUTSIDE LEADING EDGE SKIN
WING TIP - TOP AND BOTTOM

EXTERNAL LOCATIONS OF MAGNESIUM ON THE B-36

EASTERN AIR LINES, INC.

New York, N.Y.

The research and development policy of Eastern Air Lines, Inc., is based on the premise that it is a transportation agency created to serve the traveling public and that, unless it provides a distinct and needed dependable and reliable service, it fails to accomplish its purpose; also, that basic research and development problems can be best handled by the equipment manufacturers, who, as a rule, have the necessary facilities to reach solutions promptly, efficiently, and economically.

Thus, the principal objectives of air-line engineering are:

(1) To improve all the phases of flight safety and operation.

(2) To design for maintenance in order to simplify servicing, reduce costs, and increase airplane utilization.

(3) To define special problems to the manufacturers for solution and improvement.

(4) To prepare new aircraft design specifications for the manufacturer's guidance so that each subsequent aircraft purchased by Eastern will be more reliable and dependable and constitute progress in the state of the art.

(5) To coordinate new designs with aircraft, engine, and accessory manufacturers. NOTE: Eastern considers this activity most important, because close coordination with the manufacturers during the design and manufacture of new type aircraft is conducive to greater flight safety and lower maintenance and service costs when such aircraft are subsequently inducted in scheduled air-line service.

Among the many developments initiated by Eastern Air Lines during the past decade, the following bear citation:

(1) Development of the *Vacuum Pump Fusible Plug* to eliminate excessive operating temperatures and resultant fires.

(2) Development of the *Double-Loop Fire Detector Circuit* to improve the reliability of aircraft fire detection system; this was adopted as standard by Lockheed Aircraft Corporation.

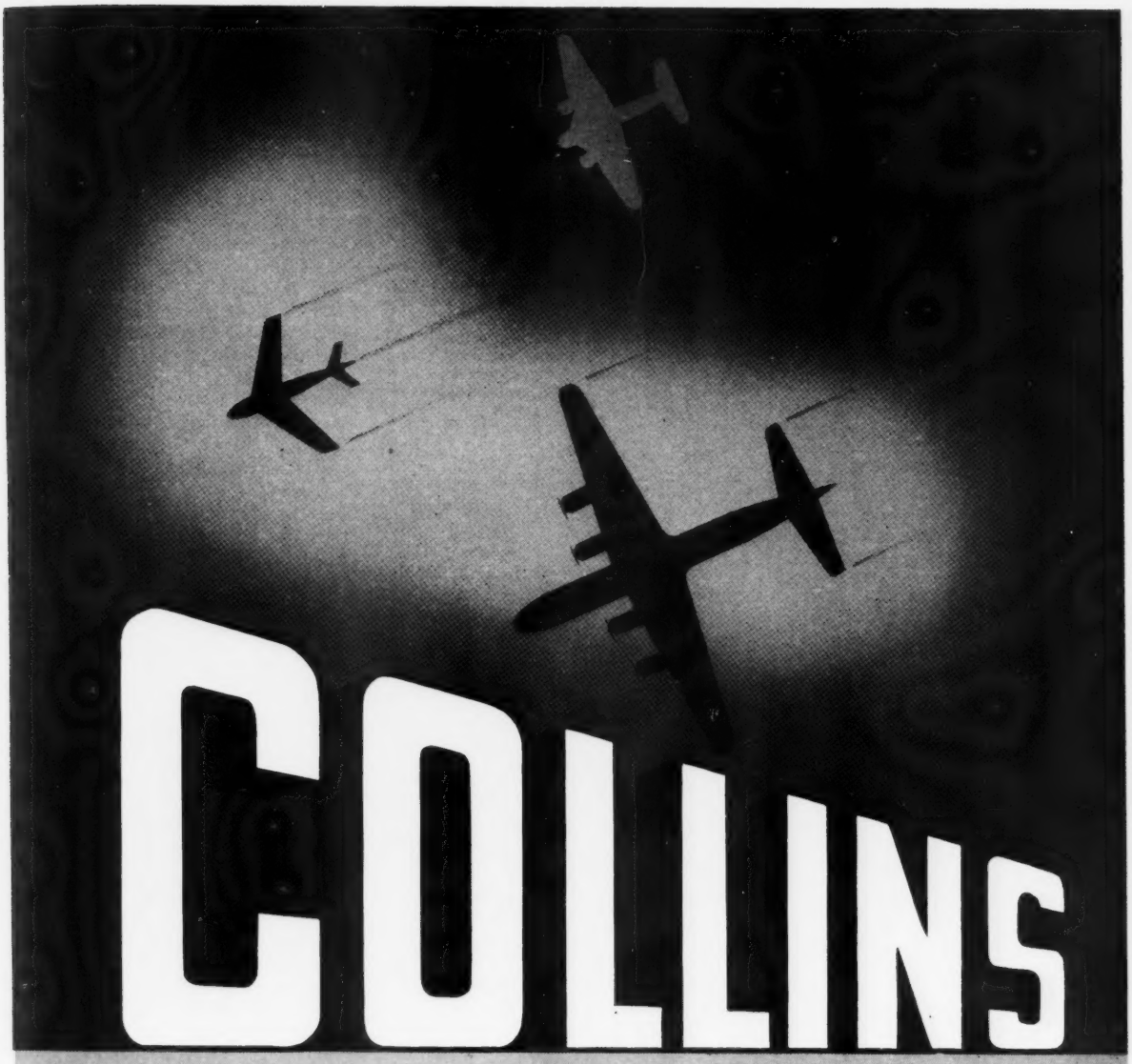
(3) Research in *indirect lighting* for cockpit instrument board to reduce pilot fatigue by improving instrument dial visibility and eliminating glare.

(4) *ALPA-ATA centerline and cross-bar airport runway approach lighting system*, adopted by the CAA and ICAO.

(5) Improvements in *life vests and life rafts* to increase their effectiveness.

(6) Improvements in *propeller reversing circuit* to provide greater reliability and reduce inadvertent malfunction to a minimum.

(7) Development of an improved *magnetic sump plug* for internal combustion engines.



the leading name in aviation radio and electronic navigation equipment

First choice with major airlines the world over

Standard equipment on all Air Force and Navy fighters and bombers

Preferred by private and executive aircraft owners everywhere

COLLINS RADIO COMPANY, Cedar Rapids, Iowa

COLLINS

11 W. 42nd Street
NEW YORK 36

1930 Hi-Line Drive
DALLAS 2

2700 W. Olive Avenue
BURBANK

(8) Active participation in the NACA ice accretion recording program and NACA VG recording tests.

(9) Special studies on the degree of turbulence in fronts and line squalls. Recently, members of the Meteorological Department have received wide recognition for the development of methods of forecasting movements of cyclones and their future intensity; also, the development of a systematic and successful method for forecasting the formation of new cycles before their occurrence.

In addition, personnel of Eastern Air Lines are participating members of numerous Government and industry committees, among which can be cited: (a) NACA Committee on Operating Problems; (b) NACA Sub-Committee on Aircraft Noise; (c) NACA Sub-Committee on Meteorology; (d) CAA-CAB-ATA Advisory Committee on Aircraft Performance; (e) ASTM Committee D-2 on Fuels; (f) SAE Committees A-2—Aircraft Electrical, A-5—Wheels and Brakes, and S-7—Cockpit Standardization; (g) ATA Committees on Jet Transport Specifications, Helicopters, Crash Survival, Ground Equipment, Purchasing, Aircraft Seating, and Engineering and Maintenance; (h) AIEE Committee on Voltage Regulators and Protective Devices; and (i) Industry Committees on Airline Terminals for the New York-Metropolitan Area.

CHARLES FROESCH
Vice-President—Engineering

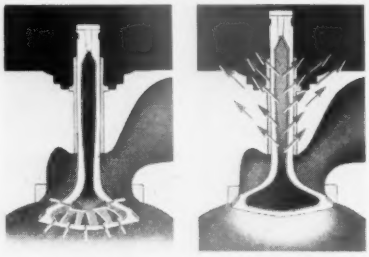
EATON MANUFACTURING COMPANY

Cleveland, Ohio

At the end of World War I, engineers in many countries were experimenting with so-called "self-cooled" valves. The first to be successful was an engineer at McCook Field. In 1922 he conceived the idea of a hollow valve partly filled with sodium and potassium salts. In operation, the salts liquefied and splashed from one part of the valve to another, picking up heat from the valve head and transferring it to the stem, where it was dissipated into the guide, cylinder head, and cooling system.

The Eaton organization, in cooperation with the Army Air Force, took over the development and perfecting of the idea, as well as the solution of the knotty production problems involved in forging and machining the highly precise internal cavity. Metallic sodium later proved superior to the salts originally used, and this type of valve become known as the sodium-cooled valve.

Sodium-cooled valves permitted the building of engines with previously undreamed-of power. By the beginning of World War II, they were used in all aircraft engines of 300 or more hp. Sodium-cooled valves have literally made possible the modern reciprocating aircraft engine; they have been one of the most important single factors in the development of commercial and military aviation.



At operating temperatures, the sodium inside the valve liquefies. At the left, arrows show how heat is picked up by the sodium from the extremely hot valve head. Motion of the valve agitates the liquid sodium, transferring heat from the head to the cooler stem. At the right, arrows show how heat is dissipated into the valve guide, cylinder head, and cooling system.

Eaton has been privileged to work in close cooperation with the aircraft industry in developing many other advancements and in furnishing such vital parts and equipment as valves, valve seat inserts, hydraulic valve lifters, tappets, coil springs, dynamometers, and turbojet engine parts.

EDO CORPORATION

College Point, L.I., N.Y.

Twenty-eight years ago the Edo Aircraft Corporation was formed on a bayside plot of land on Flushing Bay just across from where LaGuardia Field is now located. The new company at College Point, within the city limits of New York, was formed by Earl D. Osborn, from whose initials the company's name was derived, for the purpose of designing improved seaplanes.

After building a 110-hp. all-metal flying boat called the "Malolo," the company switched its attention to building all-metal seaplane floats that would permit the conversion of most landplanes to water use. Since 1926, when the first scow-shaped Edo floats were installed on a Waco 9 of the Ludington Exhibition Company, more than 400 different types of aircraft have been equipped with Edo floats, including many trail-blazing planes such as Lindbergh's Lockheed, Byrd's Condor and Balchen's antarctic-spanning Northrop.

Because of the company's early application of aluminum to the construction of aircraft components, the company developed many techniques that are now well known in the aircraft industry. To reduce salt-water corrosion, the company made the first commercial application of the anodic process of treating aluminum. It helped pioneer in the use of the stretch press. As a result, Edo was called upon to build a number of aircraft, including the Courtney amphibian for Curtiss and the Seversky amphibian, forerunner of today's Republic fighters. During World War II, virtually all the floats for the Navy and Air Force came from Edo's enlarged College Point plant, which employed 2,440 people in 1944. At the end of the War, the Edo OSE, a scout-observation airplane designed for the Navy, was produced in limited quantities.

Diversification of the company's activities led to a change in name to the Edo Corporation in 1947, and since then the company has become a principal designer and manufacturer of underwater detection equipment for the United States Navy. It has also undertaken a wide variety of research and development projects of a classified nature for the armed services. Among the diversified products designed and manufactured by Edo are deep depth sounders, ASW equipment, air-borne lifeboats, arctic cargo launches, submarine periscope fairings, radar nacelles, and other external stores. Various aircraft components such as F-84 tail surfaces, Grumman wing-tip floats, and other parts have been built by Edo under subcontract.

The company continues to build commercial seaplane floats and has played an important part in recent technical improvements in water flying.

Using a modified Widgeon amphibian, Edo has conducted for the Navy flight evaluation tests on a number of new hull shapes designed for more efficient flying boat use. Much of the early flight-test and development work on the hydroski was conducted by Edo for both the Air Force and the Navy under a series of experiments over the past 6 years.

As Chairman of the Board, Mr. Osborn maintains active participation in the company's management and continues to keep his hand in at flying with his own seaplane.

ELASTIC STOP NUT CORPORATION OF AMERICA

Union, N.J.

The introduction of Elastic Stop nuts in 1927 made available for the first time a simple positive method of obtaining vibration-proof bolt and screw connections. Acceptance by the air-

tonight

This man could almost reach the moon tonight... for he stands at the brink of a new age in the conquest of space, and he knows this:

If we had to, we could get him there. Given time and urgent need, we could design, build and deliver the total solution to that problem.

An entirely new development in the aircraft industry now makes this possible. It is known as Systems Engineering... a science and a method of developing aircraft, guided missiles and electronic systems not as traditional flying vehicles but as fully coordinated solutions to operations problems.

Today, Martin Systems Engineering is already in full operation, tailoring airpower to tomorrow's needs. Most of the story is under wraps, but you should know this:

If our security requirements should demand the equivalent of an "Operations Moon," the principles of Martin Systems Engineering would be essential to the solution of that problem.

You will hear more about Martin!

Martin AIRCRAFT

THE GLENN L. MARTIN COMPANY
BALTIMORE • MARYLAND

craft industry has been so complete that today every airplane and every major aircraft engine made in the U.S. and Canada uses Elastic Stop nuts.

Once assembled, an Elastic Stop nut is automatically and permanently locked to the bolt, until removed, by a fiber or nylon collar integral with the nut. Yet the nut is easily and quickly removed for inspection and repair operations and is highly reusable. Because the locking collar is made from an elastic material, neither bolt threads nor plating is damaged.

These nuts replaced castellated nuts locked with cotter pins or lockwire for most aircraft bolted joints. In terms of assembly time and labor requirements, mass production of aircraft in World War II would have been almost impossible if every important structural fastening had been cotter-pinned or wired. Maintenance operations would also have been slowed.

As a further contribution to mass production and speeding of inspection and maintenance, ESNA originated and pioneered, in cooperation with the aircraft industry, the development of many special fittings that ultimately became accepted as standard types of Elastic Stop nuts. Designed for prepositioning on the aircraft structure, they provide blind mounted fasteners for attaching components, subassemblies, outer skin, and access plates. Wherever assembly could be speeded, special anchor nuts, clinch nuts, or gang channel nut strips were designed to fit the specific job.

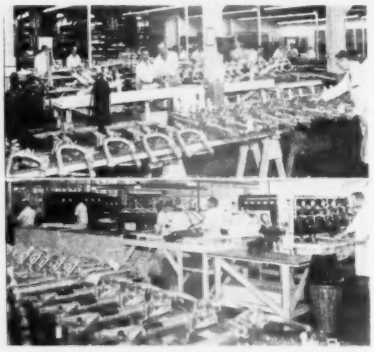
The advent of jet aircraft brought many locknut applications at temperatures too high for existing types of locknuts. For such uses ESNA developed the first all-metal locknut capable of use at temperatures up to 1,200°F. In such nuts, locking action comes from a long tapered collar that is slotted to form separate legs or beams that are offset within a carefully controlled tolerance range. This resilient beam deflection keeps uniform pressure on all bolt threads for effective nondamaging locking performance.

A more recent development by ESNA is a line of miniature hexagonal Elastic Stop nuts, as small as 0.109 in. across flats. These are expected to find extensive use in aircraft instruments, optical equipment, and guided missile controls, making available reusable vibration-proof fasteners to meet the increasing demand for miniaturization of this type of equipment.

ELECTROL INCORPORATED

Kingston, N.Y.

Since 1940, when the company converted successfully from the manufacture of oil burners to the production of hydraulic devices, engineers of Electrol Incorporated have solved a myriad of hydraulic problems, ranging from incubators to jet-plane landing gears. Among major contributions the company has made to the aviation industry are: (1) a Follow-up Directional Control Valve, used to provide precise control in remote elements, such as wing flaps, steering devices, and brakes; (2) an Aileron Booster Control Valve, which enables a pilot to fly at sonic speeds with an absolute minimum of control-stick load; (3) a hydraulic system, used for in-flight refueling; (4) a powerpak, including a complete hydraulic system for controlling wing flaps and landing gear, which may be manually or motor-operated; (5) a main landing gear, involving the use of a shrink rod, which shrinks the gear fully upon retraction into the wing; (6) a Skid Gear, designed especially to enable a particular type aircraft to land on snow or ice.



***(Top)* Electrol workmen assembling landing gear for military aircraft, helicopters, and personal planes. *(Bottom)* Electrol hydraulic devices are thoroughly inspected and tested prior to shipment.**

ESSO STANDARD OIL COMPANY

New York, N.Y.

Esso Standard Oil Company and its affiliates have pioneered in the development of many important aviation products including hydraulic oils, greases, engine corrosion preventive compounds, and fuels and lubricants for both piston- and gas-turbine-powered aircraft.

Petroleum base lubricants were quickly developed which were suitable for the earliest British turbojet engines. These were promptly followed by similar products meeting all requirements of the later U.S. turbojet engines.

The quest for maximum jet aircraft and engine performance has led to oil temperatures higher than can be tolerated by petroleum base jet oils, and the advent of turboprop engines has called for oils of high load-carrying ability. Esso affiliates have assisted materially in enabling these latest engines to attain their present full potentialities by developing an entirely new line of synthetic oils combining reasonable viscosity at all operating temperatures with low volatility, high load-carrying capacity, and good thermal stability and corrosion resistance.

More recently, rust-inhibited versions of these synthetic oils have been found satisfactory for all production engine testing and preservation operations in the engine builders' plants.

These synthetic oils are currently standard for use in all high output gas-turbine engines in England and the United States.

ETHYL CORPORATION

New York, N.Y.

The more important contributions of the Ethyl Corporation to aviation progress have been lead antiknock fluid (hereafter lead) and the discovery of the antiknock properties of the branched chain paraffin hydrocarbons. The antiknock properties of lead (tetraethyl) were discovered by Midgley, Boyd, and Kettering at General Motors.

Investigation of the branched chain paraffins by Graham Edgar, of Ethyl Corporation, resulted in the octane number scale, but, more importantly, it resulted in 100-octane number (hereafter ON) aviation gasoline.

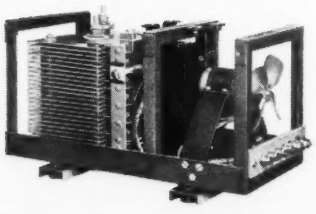
In 1928 the ON of U.S. aviation gasoline was about 55. Addition of lead to this gasoline increased its antiknock value by about 50 per cent and started the U.S. program of increasing antiknock value of aviation gasoline. In 1934, 91 ON was the practical limit of antiknock value until the U.S. Army Air Force blended it with iso-octane, a branched chain paraffin. This produced the first 100 ON aviation gasoline and a 30 per cent increase of power over that available with 91 ON. The current Grade 115/145 has almost four times the antiknock value of 55 ON and has permitted engine power to be more than doubled. Grade 115/145 contains a minimum of about 60 per cent of branched chain paraffins, and lead contributes about one-third of its antiknock value.

FAIRCHILD CAMERA AND INSTRUMENT CORPORATION

Syosset, L.I., N.Y.

Sherman M. Fairchild designed and developed the first aerial camera with a between-the-lens shutter in 1920. This development of a precision aerial camera actually resulted in the birth of three

Federal supplies the 50-Amp. Transformer-Rectifier unit used in the Stratofortress... "America's new double-edged weapon"



FTR 3146-BS AIRBORNE POWER SUPPLY

● **AC Input:** 195-210 volts; ● **DC Output:** 50 amps.; 24-31 volts; 380-420 cycles; 3 phase. resistive-inductive load.
● **Ripple:** 5% maximum ● **Weight:** 19 pounds
● **Dimensions:** 15⅛" long; 9" wide; 8¼" high.

Over 300,000 pounds of precision production... 185 feet from wing tip to wing tip... drawing its unique speed and ceiling from eight powerful jet engines! That's the Boeing B-52... built to serve as a deterrent against aggression... as a weapon of offense, if needed by our strategic air arm!

In the "tradition of rugged dependability" established by Boeing's famous Flying Fortresses and Superforts, Boeing has selected Federal's 3146-BS Airborne Power Supply to provide the B-52 with a DC output of 50 amperes, 28 volts.

Federal's 3146-BS is only one of a complete line of rugged, compact and efficient airborne and ground power supplies developed to meet aviation's growing trend from *generated* DC to 400-cycle AC... to furnish *dependable* DC power where required. Federal equipments are designed without expendable parts that require frequent replacement. And all are powered by Federal Selenium Rectifiers... *first* in the field... outstanding for long service life and trouble-free performance!

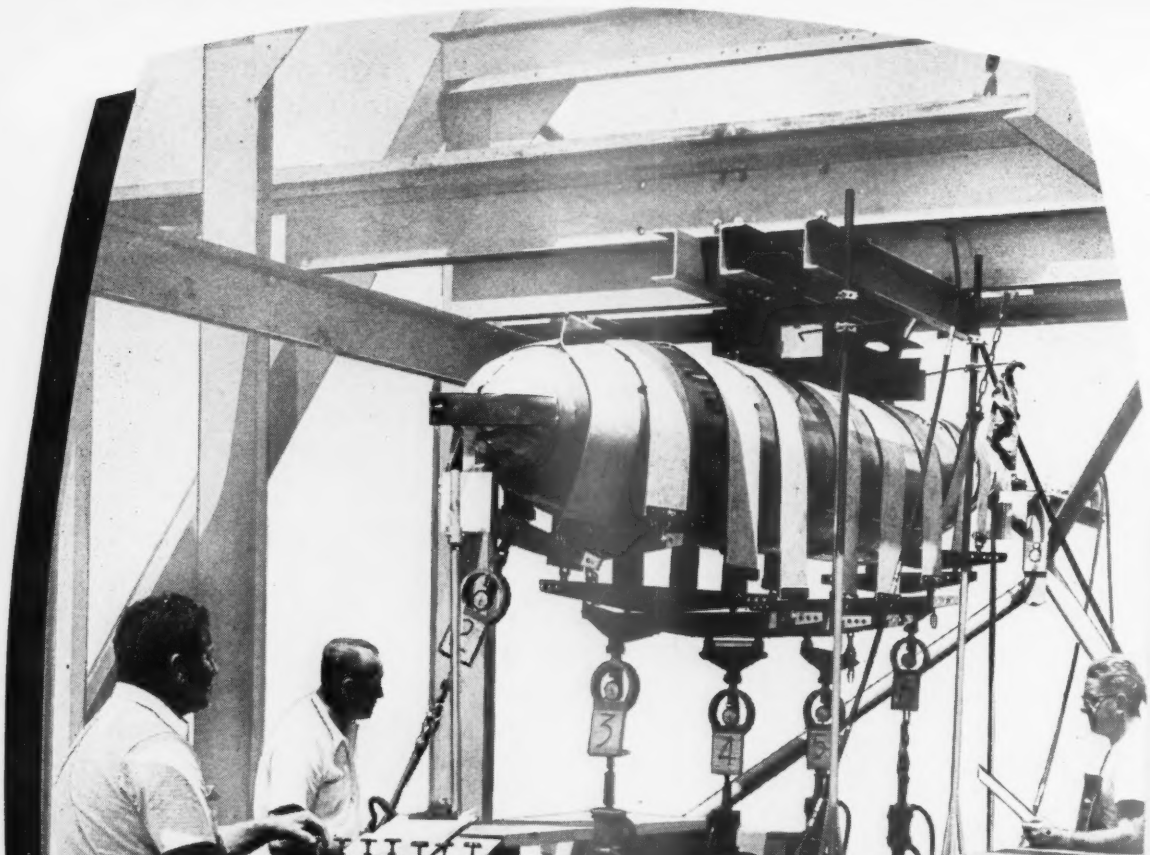
Whatever your DC requirements, write to Dept. E-569.

FEDERAL TELEPHONE & RADIO — FTR — DIVISION OF IT&T

Federal Telephone and Radio Company

SELENIUM-INTELIN DEPARTMENT **100 KINGSLAND ROAD, CLIFTON, N. J.**

In Canada: Federal Electric Manufacturing Company, Ltd., Montreal, P. Q.
Export Distributors: International Standard Electric Corp., 67 Broad St., N. Y.



Research is Part of Our Future

RESEARCH • DESIGN • DEVELOPMENT • PRODUCTION

PASTUSHIN AVIATION CORPORATION

LOS ANGELES INTERNATIONAL AIRPORT, LOS ANGELES, CALIFORNIA

phases of the aviation industry in which the United States today leads the world—high-precision aerial reconnaissance and mapping camera industry, the science and application of photogrammetry, and the aerial surveying industry.

Seeking to find peacetime uses of aerial photography, Fairchild formed a subsidiary company, Fairchild Aerial Surveys, Inc., in 1924 which pioneered in aerial mapping for civilian agencies. At about the same time the company developed the stereoscope method for aerial photographic interpretation.

In the late 1920's and early 1930's the company continued to refine the aerial camera and develop new and more precise models for new applications. In 1938, Fairchild Camera and Instrument developed the F-51 aerial camera, the first to meet the specifications of the American Society of Photogrammetry. This camera was an outgrowth of the pioneering work in establishing photogrammetric methods by Fairchild Aerial Surveys, Inc.

Based on early aerial gunnery experience with fire-control problems, the company developed the K-8 Computing Gunsight in 1939, the first electronic device of its type for air-to-air gunnery.

Numerous other mechanical, electrical, electronic, electromagnetic and optical developments, such as the radio compass, ground position computers, electronic control systems, and various types of high-precision aerial photographic equipment have helped to bring American aviation and aerial photography to world leadership during the 33 years of Fairchild history.

FAIRCHILD ENGINE AND AIRPLANE CORPORATION

Hagerstown, Md.

The Fairchild Engine and Airplane Corporation is primarily a military contractor for highly specialized needs of the military services. This close relationship with the military reflects the tenor of our times. All divisions of the corporation are engaged in extensive research and development work. These many projects are in keeping with the Fairchild tradition of pioneering in new fields and new products and in realizing a policy of progress and growth.

The Corporation consists of four divisions: Stratos, Guided Missiles, Engine, and the Aircraft Division. The headquarters of the corporation, where policy is formulated and control of the four divisions is exercised, is located in Hagerstown, Md.

The Fairchild Aircraft Division had its beginning in a small wooden shed combined with a garage then known as the Kreider-Reisner Aircraft Company, Inc. This was in 1925. A year later, two enterprising Hagerstown businessmen, Ammon Kreider and L. E. Reisner, entered their first hand-made plane in the Scientific American Trophy Race—and won.

This first plane became the prototype of the famed "Challenger" plane. Already Kreider-Reisner had grown too large for the "little green shack" as they built over 100 of these planes during the next couple of years.

The Sherman Fairchild interests acquired control of the Kreider-Reisner company early in 1929. A new plant of 50,000 sq.ft. was built to allow production of the Challenger to speed up the then record-breaking rate of one plane per day. The name of the company, too, was changed to Fairchild Aviation Corporation.

Although demand for commercial aircraft was virtually at a standstill during the depression years, Fairchild retained its engineering staff and designed the F-22 and F-24, the latter a two-place, side-by-side, high-wing monoplane that proved to be most popular as a private cabin plane. During these years Fairchild also designed an experimental, single-engined cargo plane for the Army Air Corps, as well as an all-metal amphibious F-91 "Baby Clipper" for use in South America by Pan American Airways.

The corporation was reorganized in 1936 as the Fairchild Engine and Airplane Corporation, assuming the basic structure as it exists today.

In 1938 Fairchild entered the military field with the development and production of the famous PT-19 primary trainer, a low-wing two-place monoplane. Over 5,000 of these PT-19 "Cornells" were produced for the U.S. Air Force. During the war, thousands of aviation cadets received their initial flight training in Fairchild's trainer. At the height of the aviation training program, four other manufacturers in the U.S., Canada, and Brazil also produced the PT-19.

Under subcontracts from The Glenn L. Martin Company, war work at Fairchild also included the production of tail surfaces and wings for Martin bombers and PBM flying boats.

In 1942 the company's first "all-wood" (Duramold) advanced twin-engined trainer was flown. A separate plant was constructed in Burlington, N.C., to produce this unique plastic-bonded plywood plane, the AT-21 "Gunner," designed to relieve the critical metal shortage. Fairchild's "Duramold" process made it possible to build such a molded plywood aircraft.

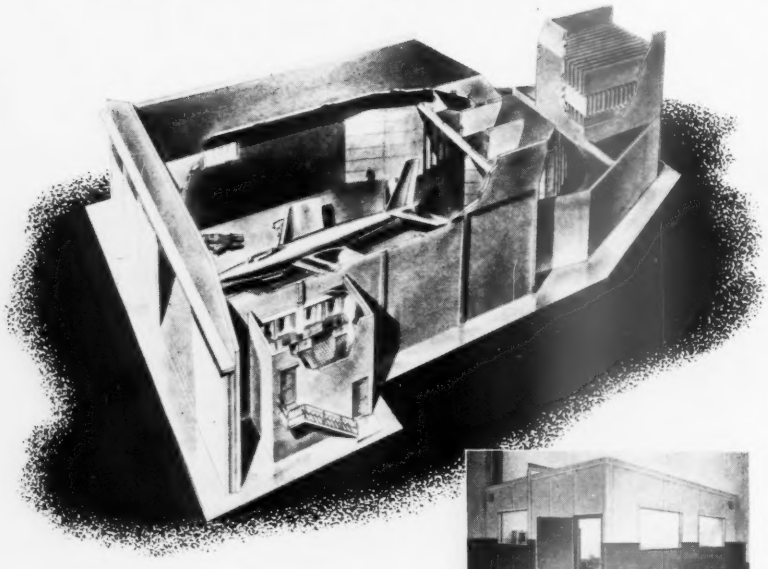
Late in the war years, Fairchild Aircraft began the development of what

(From top to bottom) (1) F-91 single-engined amphibian, 1935. (2) PT-19 primary trainer. (3) AT-21 gunnery trainer. (4) C-82. (5) C-119.

was destined to become its best known product—the series of revolutionary transport planes designed for the "All-Air Army." Because of its tremendous loading capacities the first model, the C-82, soon won the nickname of "Flying Boxcar." It became the standard cargo and transport plane for the Army's airborne operations.

During the 321-day Berlin Blockade in the hectic days after World War II, Fairchild C-82's were on the job with other cargo planes of the United Nations maintaining the spectacular air lift, keeping the stricken city alive. In the blizzard of 1949, these same Fairchild planes flew to the rescue of western ranchers to enhance their reputations during "Operation Haylift."

WHATEVER YOUR NOISE PROBLEM
ISC has the right answer

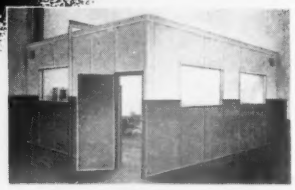


In 1936, ISC first silenced an aircraft test cell. Since then ISC has continued to pioneer the control of aviation noise . . . big and small . . . menace or nuisance.

Typical is the "Hush House" illustrated above. "Run-up" test buildings of this type provide complete all-weather test facilities for jet and reciprocating engines. They may be used for run-up testing right in the plane . . . with single or double jet engines, with or without after-burners . . . provide up to 60 decibels noise reduction.

ISC experience, engineering "know-how" and extensive facilities are available to help you. Whether you require machinery enclosures, soundproof rooms, run-up mufflers or development of a complete testing facility, ISC can do the *whole* job: analyze your problem, design, manufacture and install the necessary acoustical equipment.

If you require quiet in any phase of your operation, consult ISC.



Control rooms and plant offices are effectively soundproofed when constructed of ISC "Soundmetal" panels. Units are easily erected and dismantled . . . provide noise-free working quarters at low cost.

ISC Machinery Enclosures provide a flexible and efficient means of isolating noisy machinery . . . even reduce noise intensity WITHIN the enclosure. Adaptability of "Soundmetal" panels permits their use around bulky or odd shaped machinery.

ISC "Run-Up" Mufflers permit testing at the plant or on the airstrip . . . give up to 60 decibels noise reduction . . . withstand high temperatures and velocities. Mufflers can be designed to meet requirement of all types of jet planes.

SILENCE SERVICE

Industrial Sound Control Inc.

45 Granby Street, Hartford 12, Conn.

At the conclusion of the contract for the C-82's, the Aircraft Division began production of an improved version known as the C-119 Flying Boxcar. Combining higher pay load with greater power and maneuverability, the new Fairchild C-119 proved to be even more versatile as a cargo and transport plane than its predecessor.

Before the Korean conflict, in giant military maneuvers Fairchild's Flying Boxcars demonstrated how a large-scale operation could be supplied and maintained efficiently by air as thousands of men and tons of supplies were air-dropped into a simulated combat area.

At the present time Fairchild is solely engaged in producing C-119's for the military services. In the Korean War they have proved to be invaluable to the newly formed Combat Cargo Command, the first Air Force Command devoted to transporting troops and equipment from rear areas to the front lines. Korea has seen the Flying Boxcar used for carrying anything from cigarettes to bulldozers, jeeps to bridge sections.

Virtually a boxcar with wings, the C-119 can carry 62 fully equipped men and either parachute them to their objective or land them at an airhead. In a matter of minutes, the aircraft can be transformed into a flying ambulance, carrying 35 litter patients plus attendants to rear-area hospitals. Its ease of loading and tremendous cargo-carrying capacity have made possible air-borne operations never before considered feasible. Specifically designed for troop and cargo carrying, the Flying Boxcar is perfectly suited for its role in the new "air-transportable Army."

The current trend of thinking in our Defense Department has been toward the concept of "air lift," which calls for the complete air transportability of men, weapons, equipment, and supplies. Fairchild's Flying Boxcars were designed with this concept of air-borne strategy in mind and can carry most of the weapons, vehicles, and equipment used by the standard infantry division.

What of tomorrow? Improvements are continually being made on the C-119. Another radically different version of the Flying Boxcar is now being tested. Future planning in cargo planes will, to a great extent, be dependent upon the needs of the military establishment to meet ever changing world conditions.

The drawing boards at Fairchild go beyond the Flying Boxcar. The company is looking ahead to other requirements of the military. Planning at Fairchild is dedicated to the defense of our nation and the progress of man's efforts to conquer the skies.

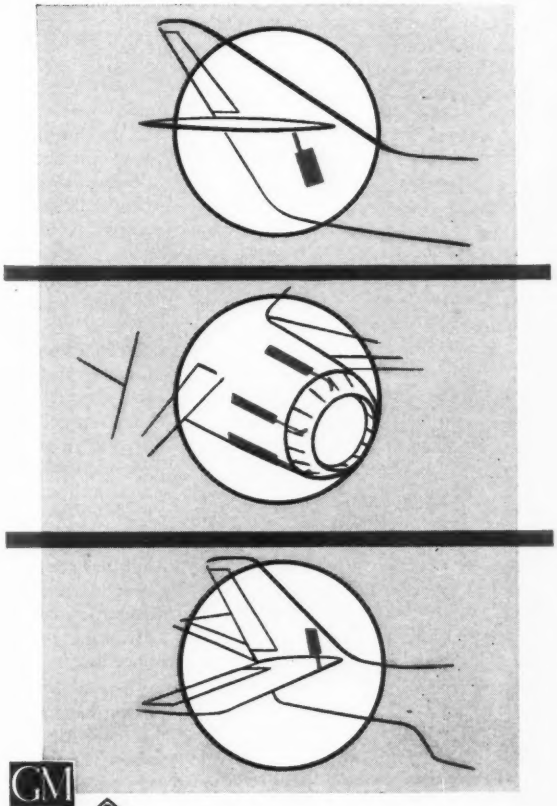
AEROPRODUCTS SELF-LOCKING ACTUATORS PERMIT INSTANT FLIGHT SURFACE CONTROL

AEROPRODUCTS SELF-LOCKING ACTUATORS MAKE POSSIBLE THE INSTANT, ABSOLUTE CONTROL OF MOVABLE AIRCRAFT SURFACES. AN AEROPRODUCTS ACTUATOR WILL ADJUST A MOVABLE SURFACE TO ANY POSITION WITHIN THE DESIGN RANGE, LOCK THE SURFACE IN THE SELECTED POSITION, AND HOLD IT UNTIL CHANGE IS REQUIRED.

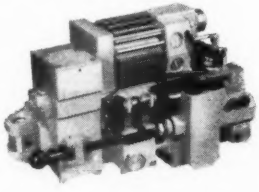
The power source for Aeroproducts actuators may be hydraulic, pneumatic, electric or manual—or any combination of these. Actuators can be readily synchronized in tandem or in series to provide coordinated control of related movements.

Announced applications of Aeroproducts self-locking actuators include control of the flyable tail in a jet fighter, the horizontal stabilizer in another, and the afterburner exhaust nozzle in a new high performance jet engine. Additional applications include control of wing flaps, dive brakes, cargo doors or ramps, variable wing sweep and incidence, wing fold and canopy slides, turbojet guide vanes.

Let us know your requirements for aircraft actuators. Your inquiry will receive prompt attention.



Typical Aeroproducts Actuator



Aeroproducts

GM GENERAL MOTORS AEROPRODUCTS GM

Building for today
Designing for tomorrow

ALLISON DIVISION • GENERAL MOTORS CORPORATION • DAYTON, OHIO

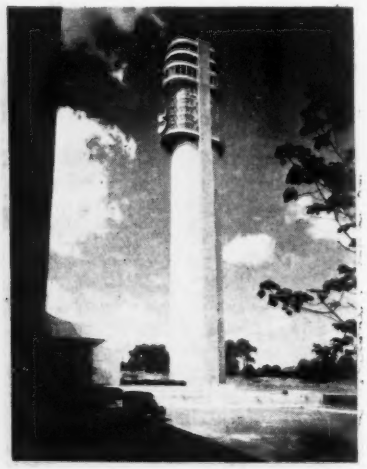
FEDERAL TELECOMMUNICATION LABORATORIES, INC.

Nutley, N.J.

Since the advent of radio into aeronautics, the development of aerial navigation and communication aids has occupied an increasingly important role in the activities of the International Telephone & Telegraph Corporation.

Companies of the IT&T System pioneered the instantaneous direction finder in 1935 and produced the first successful Instrument Landing System (ILS) before World War II. Their wartime improvements in ILS later formed the basis of the commercial system adopted by the International Civil Aviation Organization (ICAO).

In the radar field, approximately half of the precision-approach and air-surveillance radar equipment for the GCA (Ground Controlled Approach) systems used by the U.S. Armed Forces during World War II were of IT&T origin. Equally significant have been the System's contributions to the development of VOR (very high frequency omnidirectional range) and DME (distance measuring equipment), which together constitute the new, accurate radio navigation aid of the airways. The DME is a combination of ground and air-borne radar designed to provide the pilot with a continuous and accurate indication of distances from his plane to a selected ground station. Between 80 and 90 per cent of the four-course radio ranges originally installed for the navigation of commercial air liners—may of which are still in operation throughout the world—were manufactured by IT&T System companies.



Research Center of International Telephone and Telegraph Corporation—the Microwave Tower, Federal Telecommunication Laboratories, Nutley, N.J.

Since World War II, IT&T collaboration with the U.S. Government has yielded a number of new developments, notably airport VHF airport direction finders and surveillance radar. Other radio communication and navigation devices produced by the IT&T System include air-borne and ground transmitters and receivers, including ILS receivers; LORAN (Long Range Aid to Navigation); and electronic altimeters.

FIRESTONE TIRE & RUBBER COMPANY

Akron, Ohio

In the vanguard of the quest for speed, Firestone in 1953 is manufacturing electronically controlled rockets, vital parts of jet aircraft engines, and tires that will safely land aircraft at speeds above 250 m.p.h.

In steel, plastics, and rubber, Firestone is making new discoveries for the military forces under its many research and development contracts. And, in production, many of the Company's facilities are producing such items as high-speed tow targets, aircraft rockets, artillery shell, 90-mm. cannon, 3-in. antiaircraft twin-gun mounts, recoilless rifles, bullet-sealing aircraft fuel cells, and thousands of aircraft tires.

Since 1933, when Firestone made the first synthetic airplane tires, continuous research work has been devoted to the formulation and production of new and better rubber for tires and other uses. As a result, Firestone now can make tires that will retain their resiliency at temperatures far below zero.

Several new types of tires were developed during World War II to enable military aircraft to operate from African deserts, Pacific coral atolls, and steel landing mats in jungle areas. One of the most outstanding of these tires was the Channel Tread which was developed by Firestone engineers. This tire was designed so it would roll over the top of mud and sand instead of sinking into it.

All of the aircraft tires used by the military services during and since World War II have incorporated the tire-construction principles developed by Firestone on the Indianapolis Motor Speedway.

The high-speed testing experience of Firestone engineers enabled them again to meet Air Force requirements in 1952 when the first of a series of tires completed 50 simulated landings on a laboratory runway at speeds of 250 m.p.h.

Early in 1953, Firestone again pioneered in the production and successful testing of the first main-wheel tubeless airplane tire. This was flight-tested by the Navy in March. Designed by Firestone to reduce the weight of airplanes, Nylon fabric is used in this new tire. It is 20 per cent lighter in weight than the postwar airplane rayon tire and tube, and, depending upon the size of plane, total weightsavings for an airplane with the new tires can range from 7 to 125 lbs.

FLETCHER AVIATION CORPORATION

Pasadena, Calif.

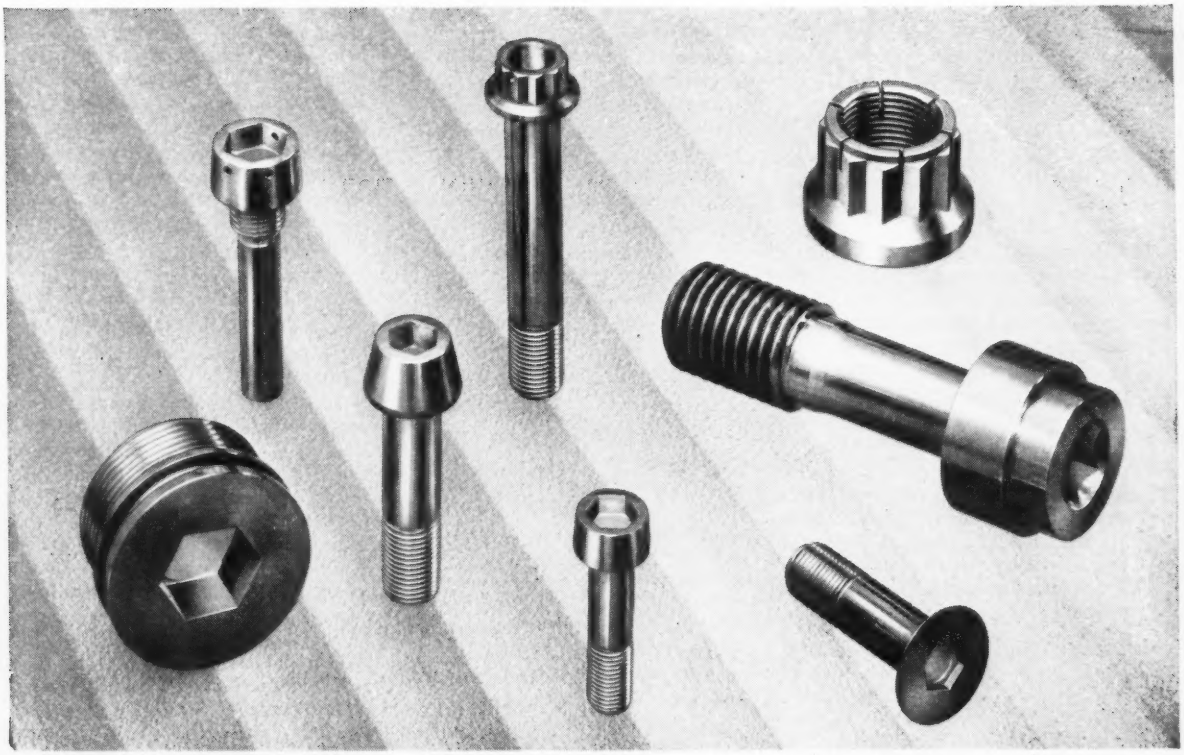
The most noteworthy development that Fletcher Aviation has made to aviation is its expandable, jettisonable fuel tank. Early in 1945, when the JT-22 airplane was in design, Wendell Fletcher, President and Chief Engineer, reasoned that a jettisonable fuel tank of straight cylindrical center section configuration would offer three distinct advantages: (1) that the straight cylindrical center section as averse to the then customary elliptical center section would improve the aerodynamic characteristics of the tank itself; (2) that the straight center section offered much better manufacturing and sealing possibilities; (3) and, most important, that the straight cylindrical center section provided for tank capacity change by merely varying the length of the center section or by using multiple center sections.

That all the advantages described above were worth-while has long since been proved. The last-named advantage, that of grouping center sections to make a larger tank, proved to be a design advantage of major importance at the beginning of hostilities in Korea when certain of our jets, then based in Japan, carried only enough gas to allow them 15 min. over the Korean targets. By simply adding two extra center sections, a 165-gal. tank was thus converted to 255-gal. capacity. This provided the only method of making these planes immediately available for use in the Korean area.

Fletcher Aviation refers you to an article by James H. Winchester in *Aviation Age*, December, 1950, for photographs and the story from which the following excerpts are quoted: "These wing tanks, each of which will now carry 265 gallons of fuel, are essentially the older tank, with an additional length of tank inserted in the middle.

"With these new tanks, the F-80's have a range which will compare favorably with that of the F-51. They can go out a distance of 550 nautical miles (622 statute miles), drop down to the deck, fire their rockets and machine guns, then climb back to their normal altitude of 30,000 ft. and return to base, still with a safe margin of fuel remaining in their tanks."

McDonnell Banshee uses SPS Fasteners



A typical selection of SPS Fasteners. For information, write STANDARD PRESSED STEEL CO., Jenkintown 58, Pa.

AIRCRAFT PRODUCTS DIVISION

Our Fiftieth Year : A START FOR THE FUTURE

SPS
JENKINTOWN PENNSYLVANIA

FLIGHT REFUELING, INC.

Danbury, Conn.

The growing importance of refueling aircraft while in flight, accentuated by the development of fuel-thirsty jet aircraft, has thrown the spotlight on Flight Refueling, Inc., manufacturers of the probe and drogue system of mid-air refueling which has been adopted by the United States Air Force and Navy.

Formed in 1949 at Danbury, Conn., Flight Refueling actually enjoys the benefit of over 16 years of experience in the field of mid-air refueling through its affiliated company, Flight Refueling, Ltd., in England. This latter concern, organized in 1934 by Sir Alan Cobham has pioneered in refueling techniques leading up to perfection, with United States Air Force aid, of the current simplified probe and drogue system.

Early Flight Refueling experiments resulted in the development of the looped-hose system, which was put into scheduled commercial operation in 1939 with flying boats of Imperial Airways operating nonstop across the Atlantic. This system, further perfected by subsequent postwar scheduled operations over the North Atlantic and to Bermuda from London, led to the first system adopted by the U.S. Air Force for a number of B-29 and B-50 aircraft. A highlight of this development was the nonstop flight around the world by the Boeing B-50 "Lucky Lady" in 1949 using Flight Refueling equipment.

The need for an automatic coupling system for fighter aircraft which can carry no refueling crew led to a U.S. Air Force contract with Flight Refuelling, Ltd., and the development of the probe and drogue system, now in use. It was first dramatized with the first nonstop jet-fighter flight across the North Atlantic in 1950.

The system incorporates a short probe on the receiver aircraft, which is flown into a funnel-shaped drogue trailed behind the tanker. Contact is made with less difficulty than a landing, and the fuel flows at a high rate through the hose which, because of its flexibility, permits contact and fuel transfer in rough-air conditions. One great advantage is remote operation that permits refueling aircraft from hose reel pods mounted on wing tips, allowing simultaneous refueling of several fighters.

The growing Air Force interest in the system led to the establishment of Flight Refueling, Inc., in Danbury in 1949, and since then the company has undergone considerable expansion to meet increased requirements for its equipment. Late in 1953 a controlling interest in the firm was acquired by Reaction Motors, Inc., of Rockaway, N.J., Laurence Rockefeller, and Associates.

In addition to manufacturing mid-air refueling equipment, the company also makes flexible hose couplings to connect aircraft fuel lines.

FLIGHT SAFETY FOUNDATION, INC.

New York, N.Y.

The Flight Safety Foundation disseminates accident prevention information at an industry level; it conducts closed seminars on controversial air safety problems; it gives awards for distinguished achievement or unusual acts in the furtherance of air safety; it spurs the adoption of proved safety ideas; and it publishes special studies of a practical nature on air safety problems. It is financed by the industry and interested individuals.

The Cornell-Guggenheim Aviation Safety Center deals with universities, research organizations, and designers. Its purpose is to cooperate with universities and designers so that design oversights of the past will be less likely to be repeated. This is done by the preparation and publication of "Design Notes," Human Engineering Bulletins, by publishing high-level studies on air safety, and by lectures. Over 70 universities and many manufacturers participate in this program. The Center also issues

You get
Special Engineering with...

Lamb Electric

SPECIAL APPLICATION
FRACTIONAL HORSEPOWER
MOTORS

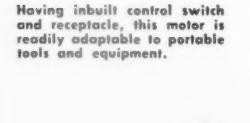
• Every Lamb Electric Motor is specially designed for the product or device it is to drive. This means that both electrical and mechanical characteristics are engineered for the exact requirements of the particular application, often resulting in savings in space, weight and cost factor.

Special engineering in Lamb Electric Motors assures optimum product performance and efficient, long-life motor operation...another reason why more and more of America's finest products are being powered with Lamb Electric Motors.

The Lamb Electric Company
Kent, Ohio

In Canada: Lamb Electric—Division of Sangamo Company Ltd.—Leaside, Ontario

Having inbuilt control switch and receptacle, this motor is readily adaptable to portable tools and equipment.



Where intermittent high torque and space economy are important, this specially developed aircraft motor provides distinct advantages.

Lamb Electric
SPECIAL APPLICATION
FRACTIONAL HORSEPOWER MOTORS

an annual report entitled "Survey of Air Safety Research." The 1953 edition contains a brief description of 1,100 current air safety research projects. In addition, it publishes a quarterly "Air Safety Digest" and arranges for lectures on air safety at meetings of technical organizations such as the Institute of the Aeronautical Sciences. The work of the two organizations complement each other.

GENERAL ELECTRIC COMPANY

Schenectady, N.Y.

The General Electric Company's 75 years of engineering research and development have provided American aviation with numerous new and improved products during its 50 years of powered flight. These range from a tiny light bulb used in many types of military and commercial planes to modern jet engines enabling man to pierce the sonic barrier.

General Electric maintains many facilities for developing, testing, and producing aviation products. Probably the best known are the facilities for producing jet engines and accessory turbines at Cincinnati, Ohio, and Lynn, Mass. However, that is not the complete picture. The following is a sample of the major aviation items produced by the company's various product departments:

Aerial camera drives
Afterburner fuel pumps
Airborne ordnance (armament)
Aircraft energizers
Air-turbine drives
Amplidynes
Amplistats
Autopilots and flight stabilizing equipment
Ballasts
Capacitors
Circuit breakers
Controls
Electric starters for jet engines
Electronic and communication systems
Engine control systems
Gas-turbine starters
Generator control systems
Generators
Heaters
Hydraulic constant-speed drives
Instruments
Jet-engine ignition systems
Motors
Propeller control devices
Rectifiers
Relays
Selsyns
Servo systems
Switches
Transformer-rectifiers
Transformers
Turbohydraulic pumps
Turbojet engines
Turbosuperchargers

Besides the pure research functions, the company maintains a flight test center in Schenectady with specialized facilities for developmental and experimental work. Another air test operation is maintained at Edwards Air Force Base, Muroc, Calif., where operational tests are also conducted.

The company maintains an international service organization for assistance and supervision in maintenance

and overhaul of all types of aircraft equipment. Technical representatives may be found at Air Force and Navy air bases where G-E equipment is flying.

Probably the most noteworthy early General Electric contribution to aviation was the development of the aircraft supercharger, which led to the development of the turbojet engine.

G-E engineers, led by Dr. Sanford A. Moss, solved the problem of engine power loss at high altitudes by developing the turbosupercharger that took thin air and compressed it to sea-level density. It was in 1918 that Dr. Moss proved aircraft engines could operate at altitude with no loss in engine horsepower.

This development became a deciding contribution to victory in World War II as the vast allied bomber armadas leveled Germany and Japanese manufacturing plants. This high-altitude bombing could not have been accomplished without the use of turbosuperchargers.

During World War II, more than 200,000 G-E designed turbosuperchargers were built for American fighting planes. And today, two weapons of this nation's Strategic Air Command—the Convair B36 bomber and the Boeing B-50 Superfortress—are equipped with G-E turbos. In addition, the Boeing Stratocruiser with its many commercial and military applications has turbosuperchargers installed on its engines.

In 1941, G-E was called upon to develop and build this nation's first jet engine. Those early pioneering years on the turbosupercharger made General Electric Company the natural choice to tackle this top secret job. A model of an English jet engine, designed by Britisher Frank Whittle, was transported to the Company's Lynn River Works for study by G-E's top turbo engineers.

On March 18, 1942, after 6 months of intensive research and development on the Whittle engine, America's first jet engine, the I-A, was successfully run in a test cell. On October 2, 1942, the Bell P-59 Airacomet with two I-A engines left the ground, and America's first jet aircraft was air-borne.

This was America's beginning of a new concept of power for aircraft. Today, G-E's Aircraft Gas Turbine Division, with plants in Evendale, Ohio, near Cincinnati, and Lynn, Mass., is producing more jet engines for the armed forces than any other builder.

Many new advances in jet-engine development have been made since the first I-A was built. Today, G-E is building "all-weather" engines capable of flying in most adverse weather conditions, new high-efficiency compressors, high-altitude starting systems, powerful engines with afterburner and developing new manufacturing techniques that have increased the efficiency of the engines, as well as reduced the use of strategic materials.

A new G-E engine, the J73, has recently been installed on the Air Force's F-86H North American Sabre jet. This new engine has more thrust than the J47 in the same diameter size.

A new Components Development Laboratory has been constructed at Evendale which is the most complete privately owned facilities in the country. It consists of an analytical investigations section, an accessory development test area, an electromechanical and aerodynamics building, and a combustion research building. This new laboratory will be responsible for producing component designs that will contribute to the overall harmony of the engine without destroying the balance on which its performance depends.

Today, planes powered by the J-47 engine include the famous North American F-86 Sabre jet series, the Navy's FJ-2 Fury, the four-jet B-45 Tornado, the Air Force's first operational jet bomber, Boeing's six-jet B-47 Stratojet, Convair's B-36 powered by six Pratt & Whitney turbosupercharged engines and four jets, and Republic's experimental XF-91.

In February, 1951, the Air Force and the Atomic Energy Commission selected the General Electric Company to develop a nuclear energy power plant for aircraft, and substantial progress is being made.

The General Electric Lamp Division in Nela Park, Cleveland, Ohio, is now automatically turning out a tiny light bulb used to illuminate the hundreds of instruments and controls in the modern military plane. Designated No. 327 the lamp was formerly constructed by hand with the use of ten-power magnifying glasses.

Twenty-five years ago, the basic work in developing airway lighting in the U.S. was conducted at the company's Schenectady Works. At that time, the company introduced rotating beacons and code beacons for airway lighting. Since then, the Lamp Division has developed the special light sources for these needs.

In 1951, General Electric became the first aviation product manufacturer to introduce an integrated line of a.c. generators and voltage regulators which were fully qualified to Government specifications. G-E is announcing a new d.c. generator for use on reciprocating engines with higher output and low

cut-in speed to meet the load growth on transport aircraft. The generator is installed on Douglas' new DC-7 air liner, soon to be operated by American, Delta, and National air lines.

Aircraft jet engines have benefited considerably in the past several years from the company's development of a capacitor discharge ignition system for jet engines to allow much faster starts at high altitudes. The new system is 80 per cent lighter than previous ignition systems and twice as powerful as before.

In 1952, the company's Meter and Instrument Department at West Lynn, Mass., became the first aircraft equipment manufacturer to develop and install a mass fuel-flowmeter system on jet aircraft. The system, termed a mass flowmeter system, is a means of accurately measuring the rate of fuel consumption by jet aircraft engines.

In recent years, the company's Aircraft Accessory Turbine Section aided aviation progress with the development of a new air turbine-drive centrifugal fuel pump. The fuel pump has reduced considerably a plane's electrical load by combining boost pump, high-pressure pump, and vapor separator into one package. Called a "turbopump," the new unit saves pounds and eliminates previous system complexity.

The precision remote control for aircraft armament has made possible faster, more accurate defensive fire for America's bombers. The Boeing B-47 is currently equipped with a G-E packaged tail defense system, allowing high-speed wide-turret coverage and a longer effective radar range. Two of the company's largest organizations—Aeronautic and Ordnance Systems Division in Schenectady and the Electronics Division in Syracuse—team up to produce this equipment. In 1952, A. & O. S., in cooperation with the Navy Bureau of Aeronautics, developed a G-3 autopilot that controls the plane automatically with accuracy and stability at near sonic speeds and can be used in such maneuvers as gunnery runs on enemy aircraft. The G-3 may also be used as a "yaw damper" during manual flight to stabilize the airplane and improve its steadiness as a gun platform.

G. M. GIANNINI & CO., INC.

Pasadena, Calif.

This company's contributions to the development of aviation began in the period when automatic control and telemetry were first being recognized as great new sciences. In order to provide the then new electronic circuitry with the electrical inputs required, microtorque potentiometers with negligible friction were mounted on standard dial instruments to provide a voltage ratio proportional to the air speed, altitude, or pressure measured by the panel instrument. This simple beginning led to the development of complete instruments for the translation of pressure, temperature, acceleration, altitude, and other physical parameters into electrical units of a form suitable for use by computers, autopilots, fire-control systems, and other similar devices.

During the past decade, extreme environmental conditions imposed upon air-borne equipment, rigid performance characteristics demanded by supersonic flight, and the increasing importance of reliability have combined to make necessary new instruments of extreme ruggedness, great sensitivity, and minimum size. G. M. Giannini & Co., Inc., has been representative of the flight instrumentation industry in meeting each new challenge and frequently providing the means for the next step forward in powered flight.

In recent years, the company has supplied angle-of-attack transmitters, gyroscopes, machmeters, functional altimeters, accelerometers, and temperature vanes to almost every important flight-test program conducted in this country. Today, the development of such devices as altitude controllers with 5-ft. discrimination and pressure instruments with accuracy of one part in one thousand indicate the company's first objective—to duplicate in flight the accuracy and dependability found in the laboratory.

GLOBE CORPORATION, AIRCRAFT DIVISION

Joliet, Ill.

Globe Corporation, Aircraft Division, has its principal plant at Joliet, Ill., with a second plant at Williams Bay, Wis. and flight-test crew at the Naval Air Missile Test Center, Point Mugu, Calif. The Aircraft Division has designed, developed, and manufactured aircraft since 1939. Early activity centered around the design of the "Cinema" sailplane, and until 1944 the aircraft division bore the title "Frankfort Sailplane Company," named after Frankfort, Mich., where work was done prior to joining the Globe family and moving to Joliet in 1940. Globe Corporation celebrated its 50th anniversary in 1951.

Globe Corporation's Navy radio-controlled target drone aircraft (Model No. KD6 G-2).

Accomplishments include designing and producing the first training glider, the TG-1A, used by the USAF.

In 1942 work on radio-controlled target-drone aircraft was undertaken, and in 1943 the first successful 200-m.p.h. target, OQ-6, was designed for the USAAF. A steady progressive improvement has been achieved in target-drone aircraft from the early wood and fabric covered AAF Model OQ-2A to the present all-metal Navy Model KD6G.

During World War II, Globe Corporation produced in quantity the OQ-2A, OQ-3, and OQ-14. Subsequent to the war it developed and mass-produced the KD2G pulse-jet-powered, 200-knot, target drone for the Navy and later the 200-knot propeller-driven KD6G powered with a four-cylinder, two-cycle, 80-hp. engine. Globe also developed for the Navy the 300-knot XKD5G, which was powered with a 10-in. pulse-jet engine.

THE B. F. GOODRICH COMPANY

Akron, Ohio

Research and development programs for new and improved aeronautical rubber products have been major activities of The B. F. Goodrich Company during most of the 50-year history of powered flight.

Tire research starting shortly after the Wright brothers' epoch-making flight resulted in the first cord airplane tire, introduced by B. F. Goodrich in 1909 and first used by Glenn Curtiss. This revolutionary idea in tire construction was put to work immediately to make take-offs and landings smoother and safer.

Other aeronautical "firsts" chalked up by B. F. Goodrich throughout the years include: first streamlined airplane tire (1926); first airplane De-Icer (1930); first stratosphere suit for aviators (1934); first commercial expander tube brake (1937); first commercial prerotation tire (1938); first one-piece rubber oxygen mask for aviators (1940); first nonmetallic bullet-sealing fuel tanks (1940); first tubeless tire for airplanes (1952); first high-speed jet-aircraft tire (1952).

The coming of the jet age of powered flight introduced a new set of operating conditions that demanded the "impossible" of some aeronautical rubber products. Tires used on World War II combat aircraft, for example, could not get today's faster, heavier jet fighters and bombers off the ground—nor land them safely. To meet this challenge, B. F. Goodrich research and development programs continued after World War II at a pace rivalling the company's important wartime activity in this field.

Be sure --- specify AMPHENOL quality components

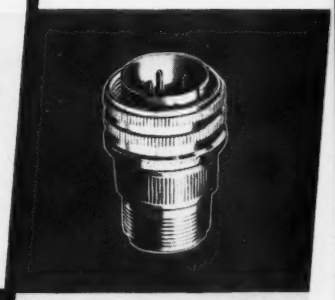
There are thousands of components used by the electronics industry that bear the famous Trade Mark of the American Phenolic Corporation—AMPHENOL. All of these are so designed and so manufactured that they will live up to the reputation for quality that is expected of this name —AMPHENOL. Manufacturers who have used AMPHENOL connectors and cables for years and those just beginning to utilize AMPHENOL components are united in the justified belief that they can always count on consistent quality with AMPHENOL.

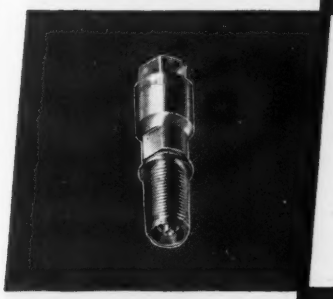
Quality from AMPHENOL is not happenstance. Rather it is the product of teamwork between engineering and production. Beginning in engineering, each new design is considered from two important viewpoints: will this product perform its task efficiently? is it the best that we can make? Components passing these tests are still subject to production analysis on material and manufacture: superior material and strictest manufacturing tolerances are demanded. Finally, the product must pass rigid inspection procedures before it is shipped to the customer.

To be *sure* of highest quality be sure and specify AMPHENOL—America's leading manufacturer of *quality* components.

AN CONNECTORS

Gold-plated contacts are now standard on all AMPHENOL AN connectors! This improvement in approved AN's is the latest result of the constant research being done by AMPHENOL to provide better electrical and mechanical performance of these critical circuit links.



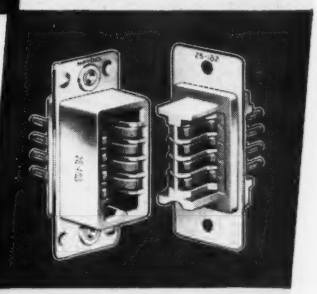


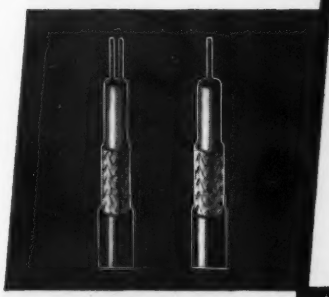
RF CONNECTORS

All AMPHENOL RF connectors are made in accordance with government specifications. The strict production and inspection procedures that AMPHENOL uses in the manufacturing of quality RF connectors, however, are *unique* with AMPHENOL. Again, quality is assured.

blue RIBBON CONNECTORS

Gold-plated contacts are also featured on AMPHENOL's blue Ribbon connectors. These connectors provide absolute ease of insertion and extraction in plug-in type sub-assemblies—incorporate the finest materials, including the new 1-501 blue dielectric.



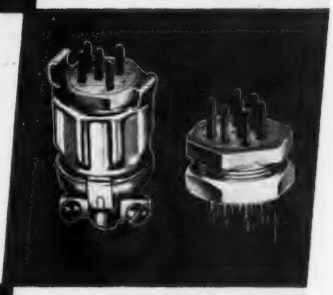


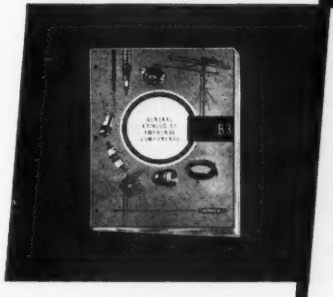
RG TYPE COAXIAL CABLES

AMPHENOL precision-manufactured coaxial cables have polyethylene or new high/low-temperature plastic dielectrics and provide years of top quality performance. Constant inspection during every phase of manufacture insures the quality of the final product.

MINIATURE CONNECTORS

AMPHENOL miniature connectors are for positive interconnection of miniature electronic equipment. Contacts are gold-plated, dielectric material is AMPHENOL 1-501 blue diallyl phthalate and hardware is nickel-plated brass. Available with either socket or pin contacts.





CATALOG B-3

The new and totally revised AMPHENOL general Catalog B-3 is just off the press. For information on the entire AMPHENOL line of quality components and miscellaneous products send for Catalog B-3.

AMERICAN PHENOLIC CORPORATION
chicago 50, *illinois*

AMPHENOL

In 1952, a new BFG aircraft tire successfully completed the Air Force program for testing aircraft tires under conditions simulating landings up to speeds of 250 m.p.h. High-speed tire performance is accomplished without sacrificing low tread wear, high load supporting capacity, and good resistance to low temperatures.

Early in 1953, the Navy's swept-wing jet fighter, the Grumman F9F-6 Cougar, became the first military airplane to fly completely equipped with BFG's newly developed tubeless airplane tires. The new tires assure safer high-speed take-offs and landings, reduce weight, and simplify assembly and maintenance.

Since B. F. Goodrich introduced the first De-Icer in 1930, the company's continuing development of the product resulted in progressive improvement that has kept the pneumatic De-Icer in step with aircraft development and airline needs. Early in 1953, B. F. Goodrich announced a new small-tube version of the De-Icer for use on high-speed aircraft. Electrically heated De-Icers, consisting of a network of tiny resistance wires imbedded in a thin rubber mat, were also pioneered by BFG.

New types of aircraft hose, developed by B. F. Goodrich since World War II, are important contributions to jet aircraft. The new hose withstands higher temperatures and higher pressures than those required in World War II aircraft.

New bullet-sealing fuel cells made by B. F. Goodrich for jet fighters and bombers are one-third lighter in weight than fuel cells used in World War II. This improvement stems from advanced construction and manufacturing techniques developed in the postwar period.

At its plant in Troy, Ohio, B. F. Goodrich makes aeronautical wheels and brakes for Air Force, Navy, commercial, and civilian aircraft of all types. A magnesium wheel produced there for use on the B-47 is rated to carry a record-breaking 60,000 lbs. and, on loading test, has supported 325,000 lbs. BFG's patented Pressure Sealing Zippers have found unique use in the aeronatuical field as aileron gap seals, as air duct seals, and as the construction feature of easily removable fume curtains.

THE GOODYEAR TIRE & RUBBER COMPANY

Akron, Ohio

The House of Goodyear salutes aviation's 50 years of progress. Goodyear has helped set the pace for this half century of powered flight. From leadership in lighter-than-air development to a commanding position in the design of modern-day aircraft and components, Goodyear has maintained its place in the vanguard of aviation accomplishment.

Goodyear became an aircraft pioneer with the introduction in 1909 of the first pneumatic airplane tire. Goodyear's development of rubberized fabrics contributed to the efficiency of early Wright brothers' and many pioneering airplanes. Other fabric types were used for the construction of the balloon section for the Vaniman airship in 1911 and Navy blimps in 1917. Goodyear's early airship pioneering was followed by production of 1,000 observation balloons and 100 nonrigid military blimps during and after World War I and the construction of the larger rigid airships *Akron* and *Macon*. Further research in the field of rubberized fabrics led to Goodyear's development of the bullet-sealing gas tank and the rubber life raft.

Pioneering in the field of lightweight, high-strength metal designs continued in the postwar period, but with World War II Goodyear's research and development in aviation received additional stimulus. In the complete aircraft category, more than 4,000 FG-1 Navy Corsairs and 150 airships were built, while major components for virtually every type of military aircraft were also produced. Goodyear was the first to design a successful electrothermal anti-icing guard and produce large aircraft laminations and a double-walled canopy that prevents internal frosting. Goodyear was also first to design and manufacture enclosures incorporating unidirectional glass fabrication and synthetic fibers in edge attachments.

Today, Goodyear is the leading producer of distortion-free aircraft canopies and optically precise laminations. Goodyear's GA 23-56 is an erosion-resistant coating, permitting the use of strong light plastic sections in jet aircraft. Bondolite,* a lightweight structural material, is extremely rigid and will not buckle or wrinkle under load.

Aircraft tires, wheels, brakes, and the cross-wind landing wheel that automatically compensates for severe cross-wind conditions have become major contributions to aviation safety. Single-disc brakes, deicers, and Airfoam* add to the safety and comfort of travel by air. The fleet of Goodyear ZPN airships being built for the Navy incorporate the latest scientific developments for antisubmarine detection and warfare.

Goodyear is a leading designer and producer of the Geda* line of analog-computing equipment, vital to all aircraft simulation studies. One of the nation's largest computer applications laboratories is Goodyear-owned and Goodyear-operated.

In the fields of aerodynamics, electronics, propulsion, plastics, and cybernetics, Goodyear is making dramatic progress in missile design and guidance, analog computation, microwave transmission, lightweight rocket motors, aircraft canopies and laminates, sandwich structures, servomechanisms, and human dynamics.

Goodyear teamwork in aeronautical design, engineering, and fabrication has achieved an enviable record during 50 years of aviation history—ever dedicated to the fundamental task of keeping "America First in the Air."

* Trade Mark, Goodyear Tire & Rubber Company or Goodyear Aircraft Corporation, Akron, Ohio.

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

Bethpage, L.I., N.Y.

The Grumman Aircraft Engineering Corporation will celebrate its Silver Anniversary next year. When it does it will be able to look back with justifiable pride to the indelible imprint it has made on the air-frame industry, where, as a pioneer in the development of Navy aviation, it has set unparalleled production records and gained universal recognition as one of the world's leading aircraft designers.

From its humble beginning in a small garage in Baldwin, L.I., 24 years ago, the Grumman organization has expanded to where it now occupies an airport and five large factories at Bethpage, while a larger airfield and buildings are under construction at the Peconic River Facility farther out on Long Island.

An unusual aspect and one of the principal reasons for Grumman's continued success is that the six men who formed the corporation in December of 1929 are still guiding its destinies. The original members are: Leroy R. Grumman, Chairman of the Board of Directors; Leon A. (Jake) Swirbul, President; William T. Schwendler, Executive Vice-President; E. Clinton Towl, Vice-President; Edmund W. Poor, Treasurer; and Joseph A. Stamm, Secretary.

Grumman began a long and valued service to the Navy early in its organization when it designed a pontoon with retractable landing gear which converted Navy catapulted scout planes to amphibians. As a result of this successful design, Grumman not only won its first Navy order, but was also awarded a contract for an experimental fighter plane.

With the development of this plane in 1933, Grumman made its historic start as a designer of Naval aircraft. Called the FF-1, this two-seater fighter caused a sensation in the aviation world, since it was the first military plane equipped with retractable landing gear and was 20 m.p.h. faster than any other fighter of its day.

Should the need arise again, the Cougar jet fighters above, plus other new Grumman Aircraft, will play as big a role in victory as did Panther jets in Korea . . . as did Grumman Wildcats, Hellcats and Avengers of task force fame in World War II.

GRUMMAN AIRCRAFT ENGINEERING CORPORATION

BETHPAGE • LONG ISLAND • NEW YORK

Grumman

Watch for NBC's Victory at Sea on your local TV station

DESIGNERS AND BUILDERS ALSO OF THE ALBATROSS TRIPHIBIAN AND THE S2F-1 SUB-KILLER

The Grumman F9F-6 Cougar.

The tiny F2F-1 single-seater biplane fighter that followed was the first to use the double-row radial engine in the military. This Pratt & Whitney R-1535-44 Twin-Wasp Junior engine gave the Grumman plane a top speed of 230 m.p.h. at 7,500 ft., placing a carrier fighter on a par with a land-based fighter for the first time.

The Navy continued to work closely with Grumman in the development of fighter aircraft, and this confidence paid off tremendously during World War II when Grumman turned out 17,000 planes and set a world's production record of 658 planes in 1 month during March of 1945.

The F4F Wildcat, with its revolutionary type folding wing, was the Navy's standard fighter at the outbreak of hostilities. By the end of 1942, the F6F Hellcat was ready. Grumman tested the experimental model in August of that year, and by December the production line began to peel them off. This phenomenal production record and the superb combat performance of this great plane won it national acclaim. Official Navy Department records credit the Hellcat with destroying two-thirds of all enemy planes accounted for by Navy and Marine airmen in the Pacific.

The TBF Avenger torpedo bomber also played a major role in the War, operating in both the Atlantic and Pacific theaters. General Motors also produced the Avenger under the designation, TBM.

When the Korean conflict broke, Grumman was again ready to serve the Navy, its F9F-5 Panther being the first jet fighter used in combat by the Navy. Its successor, the F9F-6 Cougar, a swept-wing version of the Panther, is already on the production line, and extensive Navy tests have proved that it can compete on a par with any production-operational aircraft in use today.

Although the company's amphibian branch designed such successful planes as the Gray Goose, Widgeon, and Mallard, it now devotes itself to the production of the SA-16A Albatross. Powered by two Wright R-1820 engines of 1425 hp. each, the Albatross is used in air-sea rescue work by the Navy, Air Force, and Coast Guard, the first aircraft adopted by the unified commands. The rugged and versatile ship has saved hundreds of lives in Korea and was used to great advantage in the recent earthquake catastrophe in Greece.

The Albatross has since been converted to a Triphibian—another first in aviation history—the only airplane in production which can operate from land, water, snow, and ice.

At present Grumman has three planes coming off the production lines: the Cougar; the S2F1 submarine killer, designed to do the combined work of two planes that previously operated as hunter killer teams; and the Albatross, both amphibian and triphibian versions. In addition, the company is well advanced in the production of its new top secret fighter, a lightweight simplified jet with performance far exceeding that of the capable Cougar.

HARVEY MACHINE COMPANY, INC.

Torrance, Calif.

The 40-year-old Harvey Machine Company, Inc., of Los Angeles, this year climaxed its career as a leading independent metal fabricator supplier by turning out the first successful extrusions of steel shapes for any U.S. aircraft. Pi-shaped sections of 8630 steel were delivered to Lockheed for use in attaching radomes to military Constellations. Extruded titanium shapes are next on the list and have been successfully extruded.

The steel extrusions were developed after 18 months' research by Harvey engineers based on extrusion know-how accumulated through years of supplying aluminum extrusions. They cut 70 per cent off the cost of the previous machined parts, traditionally cut from bar stock. Finished price was $8.90 each, compared with $29.40 each for machined types.

The Harvey facilities, the largest independent company in the U.S. in its field, are located in the heart of the heaviest aircraft producing section of the U.S., and Harvey is the leading supplier of aluminum aircraft extrusions. In addition, it turns out aluminum extrusions for trucks and trailers, household and building window frames and sashes, and other civilian production items.

The firm currently has eight horizontal extrusion presses ranging in capacity up to 14-in. billets and is scheduled to get the West Coast's only extrusion press to handle 32-in. billets, the largest in the nation. The firm has also begun the construction of a 54,000-ton annual production aluminum reduction plant at The Dalles, Ore. Also under way is an $18,000,000 continuous rolling mill for aluminum strip, sheets, and circular shapes, which will also be the first on the West Coast.

The firm also has a recently expanded automatic screw machine facility with over 140 multispindle units, largest installation of its type west of the Mississippi. These are used principally in the production of plumbing brass equipment and aluminum screw-machine bar products. The corporation has also installed a large bank of pressure forging presses for aluminum of considerable poundage up to 30,000 lbs.

ROBERT HEWITT ASSOCIATES

New York, N.Y.

Since the ownership and operation of aircraft by corporations for business use has grown tremendously through individual effort, but with little consolidated planning, this firm of executive aircraft consultants are offering a qualified service to present owners, to prospective owners, and to the aircraft and equipment manufacturers.

(1) Present business aircraft operations are analyzed in detail to improve safety, efficiency, and economy.

(2) Prospective aircraft owners require studies of top and middle management personnel transportation with recommendations for the most suitable aircraft and equipment, standards for flight personnel, and methods of organizing and operating a sound justifiable aviation program.

(3) Manufacturers of aircraft and equipment, realizing the potential of the corporation aircraft market, are served from a product analysis point of view eventually to replace the present aircraft, the majority of which are obsolete converted air-line or military equipment. The principal factors of economy and utility determine not only what the corporate market wants but what can be justified economically to further this already proved medium of management transportation.

Robert Hewitt Associates' aim is to improve personal executive air transportation to better serve industry as a safe, efficient, and economical supplement to our present public air transportation system.

INDUSTRIAL SOUND CONTROL, INC.

Hartford, Conn.

In the 50 years of flight, the development of aviation has been inseparably linked to the development of the aviation industry.

It is to the aviation industry that Industrial Sound Control, Inc., has made its major contributions. The firm was

Section of Early Bird mural located in the Administration Building of The Liquidometer Corporation depicting some of the pioneers and craft that played an important part in the advancement of aviation.

• *(Color reproduction and descriptive key sent on request)*

For more than 30 of the 50 years since the Wright Brothers' first powered flight, The Liquidometer Corporation has led its field in important "firsts":

FIRST Temperature and Altitude Compensated Fuel Gage.
FIRST Automatic Indication and Fuel Level Control.
FIRST Totalizing of Tanks.
FIRST Voltage Compensated Fuel Gage.

In researching capacitance gaging methods since 1940, Liquidometer introduced the:

FIRST Characterized Tank Units for different shaped tanks to provide uniform dial graduations.
FIRST Fuel Dielectric Compensation.
FIRST Double Concentric Pointer Motor Driven Indicator.
FIRST Hermetically Sealed Indicator-Power Unit Combination, eliminating separate intermediate unit between tank unit and indicator.
FIRST True Fuel Weight Indicating System automatically derived by the independent measurements of density and volume.
FIRST Spiral Scale Indicator.
FIRST Repeater indication from Motor Driven Indicator to remote D.C. Indicator.
FIRST Motor Driven Indicator with auxiliary ratiometer scales.
FIRST Use of Sub-miniature Tubes in Fuel Gage Systems.
FIRST Sub-miniature Coaxial Cable Connectors effecting large weight reduction in intercommunicating wiring.
FIRST Fuel Gage System not requiring coaxial cable.
FIRST Weight and/or Volume Indication from the same system.
FIRST Tubeless Power Unit.
FIRST Tubeless Indicator-Power Unit Combination.

Liquidometer takes pride in its accomplishments of "firsts" and no less so in its sound engineering designs, precision workmanship, rigid inspection system and the use of the highest quality materials obtainable.

WRIGHT BROTHERS 50TH YEAR ANNIVERSARY OF POWERED FLIGHT 1903 1953

LIQUIDOMETER

BE FIRST WITH LIQUIDOMETER

THE LIQUIDOMETER CORPORATION
LONG ISLAND CITY 1, NEW YORK

established in 1936 to solve a local problem that had industry-wide implications. The problem was noise—the noise produced in the testing house of a propeller plant. So annoying was the din, that the plant was being fined by the city each time it operated after 6:00 p.m. Industrial Sound Control took up the challenge of quieting the noise and, after countless experiments with techniques and materials, devised a successful installation.

During World War II, the aviation industry mushroomed across the country. Plants were set up on the fringes of residential areas. Production and testing were put on a 24-hour basis. Noise, deafening to the ears, made normal working conditions and community living impossible. It could have seriously crippled the entire production effort. But as fast as testing facilities were erected, ISC crews were on the spot to install their aggregate block soundproofing. In some instances, entire test-cell construction underwent radical changes to meet the needs of effective silencing treatment. By the end of World War II, Industiral Sound Control was responsible for more than 90 per cent of all acoustical facilities in aircraft engine plants.

After the War, ISC research and development centered on the entirely new problem of silencing jet engines. "Soundmetal" panels were devised to replace the older aggregate block constructions. Specialized mufflers, both fixed and movable, were designed for run-up testing. New materials were developed to withstand the tremendous temperatures and velocities generated during jet-engine testing.

Born of the necessities of the Cold War and the Korean conflict, larger and more powerful jet engines were being developed by the aviation industry. Plants once again were being operated around the clock near residential areas. ISC kept pace with these changes. It applied the radical "Soundstream" principle of acoustical treatment to panel and muffler design to get more effective broad-band attenuation. It designed and constructed entire test hangars for all-weather run-up testing. It created new facilities that could be quickly and economically erected right at the plant site.

At present, more than 80 per cent of all aviation acoustical installations are being designed, engineered, manufactured, and installed by Industrial Sound Control, Inc. A new plant in Rockville, Conn., is producing materials on its assembly lines. A completely equipped acoustical laboratory is being utilized to the fullest, as ISC engineering and production units combine to create the aviation industry's *first line of defense against noise.*

pressure sensitivity

The accurate measurement of pressures is basic in many of our aircraft instruments and controls. Our expanded activities now cover the four distinct yet allied fields of

- AIRCRAFT INSTRUMENTS AND CONTROLS
- OPTICAL PARTS AND DEVICES
- MINIATURE AC MOTORS
- RADIO COMMUNICATIONS AND NAVIGATION EQUIPMENT

Current production is largely destined for our defense forces; but our research facilities, our skills and talents, are available to scientists seeking solutions to instrumentation and control problems.

kollsman INSTRUMENT CORP.

ELMHURST, NEW YORK • GLENDALE, CALIFORNIA • SUBSIDIARY OF Standard COIL PRODUCTS CO., INC.

INSURANCE COMPANY OF NORTH AMERICA

Philadelphia, Pa.

The Insurance Company of North America, noted throughout the insurance industry for its progressiveness, is today considered one of this country's leading insurance companies for aviation.

The company (itself founded in 1792 at Independence Hall in Philadelphia) is actively engaging in the writing of aviation insurance and, as such, is one of the first major American stock insurance companies to offer such facilities to its agents, and to the aviation industry, as an independent company on a nationwide scale.

The interest of the Company in aviation dates almost to the origin of aviation as an instrument of commerce. As early as March of 1927, even before Lindbergh's transatlantic flight, the company commissioned a committee of its officials ". . . to study the commercial aircraft business and collect sufficient data so that our company could determine whether it would be advisable to write the various forms of Aviation Insurance."

The following year, 1928, the Company joined a group of leading stock insurance companies in the formation of a "pool," set up to offer insurance for aircraft owners. The Company continuously participated in this arrangement until 1946, at which time it withdrew from the "pool" and commenced operating its own Aviation Department, which now writes all forms of aviation insurance.

Through its early and continuous participation in the insurance of aviation risks, the Insurance Company of North America has made and is continuing a significant contribution to the development of aviation.

THE INTERNATIONAL NICKEL COMPANY, INC.

New York, N.Y.

Nickel has become an indispensable component for some of the metallic materials used in both reciprocating-engine and jet aircraft. The high-nickel alloys developed and produced by The International Nickel Company, Inc., have contributed significantly to this progress.

High-Nickel Alloys.—Inconel (77Ni-15Cr-7Fe) and Nimonic 75 (78Ni-20Cr-1.5Fe-0.4Ti) are used for the exhaust systems of piston-engine types because of high fatigue strength and good resistance to oxidation and corrosion; the alloys have been standard for commercial aircraft for several years and have been used in some military equipment. Inconel is used as combustion liners in the Allison J33 and the General Electric J47 engines to provide resistance to oxidation, thermal shock, and to buckling resulting from thermal gradients; other uses include tail-cone insulation blankets and structural support rings. Nimonic 75 is the standard alloy for the combustion liner assemblies of all English engines and for American versions of these, such as the PWA J42 and J48.

In jet aircraft, the high creep and stress-rupture strengths of Inconel "X" (73Ni-15Cr-7Fe-2.5Ti-1Al-1Cb+Ta) have resulted in its adoption for moving blades in the new engines. Inconel "W" (74Ni-15Cr-7Fe-2.4Ti-0.6Al) is a standard material for the afterburner tail cone in American engines where resistance to high bending stresses is required because the unit is supported only as a cantilever. Nimonic 80A (75Ni-20Cr-2.35Ti-1.25Al) is the standard material for blades and nozzle guides in English engines and in the American versions of these engines. Nimonic 90A (58Ni-20Co-20Cr-2.4Ti-1.1Al) and modifications of Inconel "X" are coming into use for special purposes where the service requires an acceptance test in excess of 25,000 lbs. per sq. in. for 100 hours at 1,500°F.

Ductile Iron.—The excellent combination of strength and ductility of this new engineering material enables it to be used for jet-engine burner support rings where strength and resistance to creep, growth, and warpage are mandatory. When heat-treated to a hardness level of circa 400 Brinell, the alloy is employed as a die material for forming and deep drawing the austenitic stainless steels and other heat-resisting alloys.

A nickel-alloyed Ductile Iron is employed for the main engine-bearing supports of turbojet engines to provide strength, resistance to oxidation, and resistance to corrosion in the marine atmospheres. The entire weight of the engine and a 7,200-lb. thrust at maximum output during flight bear on this assembly to the mounting trunnions. The design is produced at about one-sixth the cost of the original aluminum forging.

Ni-Resist.—Ni-Resist, Type I (15Ni-6Cu-2Cr-2Si-3C-bal.Fe) and Type II (20Ni-2Cr-2Si-3C-bal.Fe) are used as exhaust seat rings, ball joints, and valve stem guides which require high expansivity and resistance to corrosion, erosion, and galling. The alloys have good castability, can be machined easily, and retain their essential properties at temperatures up to 1,400°F.

The main bearing support in the Sapphire jet engine is Ductile Ni-Resist. This alloy has a tensile strength of the order of 60,000 lbs. per sq.in., in addition to good castability and machinability. Some Ductile Ni-Resist parts are in experimental use at 1,000°–1,300°F. and have exhibited no tendencies toward embrittlement under these severe conditions.

Alloy Steels.—Completion of this review requires a brief summary of standard uses of the heat-treated, nickel steels. This is given in Table 1.

TABLE 1
Nickel Steels

Part	SAE or AISI Number
Bolts	3135, 3140, 4635, 8635, 8637, 8742
Crankshaft and crankcase	3140, 3312, 4340, 9840
Gears	2515, 3310, 4615, 4640 8615, 8620, 9310, Nitralloy
Rods, master and connecting	3140, 4337, 4340
Propellers	4340, 4350
Propeller components	2515, 3312, 4320, 4330, 4340, 8740
Landing-gear components	4340, Modified 4340,* Ni-Cr-Mo-V*

* Mearns, William C., *Some Recent Alloy Steels and Their Heat Treatment*, Metal Treating, Vol. 4, No. 2, pp. 2–4, 10, 1953.

T. H. WICKENDEN, *Vice-President*

JACK & HEINTZ, INC.

Cleveland, Ohio

As aviation marked its 40th anniversary and the development of reciprocating engines approached full maturity, one of the most pressing problems was that of starting the higher horsepower plants. In the pioneering days of aviation, mechanics resorted to hand-turning of the propeller to "pull the engine through." This was a hazardous practice, later replaced by a safe but still manual device—the hand-cranked inertia starter connected to the crank shaft.

A significant advance in starting technique occurred with the appearance of Jack & Heintz, Inc., on the aviation scene in 1941. Ralph Heintz designed a combination electric inertia-direct cranking starter relying solely on an electric motor to rotate the engine; his design was the basis of the Company's formation. The original starter, modified to the now famous JH6 series, is in universal use on most of today's reciprocating engines ranging to 4,500-cu. in. displacement.

Of course, today's engine is the powerful turbojet whose starting power demand is much more severe than the reciprocating engine. Keeping pace, Jack & Heintz has developed electric starters to handle such turbojet engines as the J33, J34, J42, and J47. Electric power, however, is inadequate to meet rising

What JACK & HEINTZ *is doing about...*

J&H announces development of three new 8000-rpm, continuous-duty, d-c generators for jet aircraft—unique "straight-through" air path design provides maximum cooling.

High-speed accessory pads on current jet engines create the need for a generator which can operate continuously and efficiently at 8000 rpm. Present generators, designed primarily for use on reciprocating engines, do not meet that demand—high temperatures and stresses greatly reduce service life of bearings, commutators, brushes and insulation—making new generator developments a vital necessity.

Responding to this need, and nearing production on three models, J&H is the first manufacturer to announce development of essential high-speed, d-c generators for use with jet aircraft engines. All models are "true" 8000-rpm, continuous-duty, d-c generators.

J&H engineers, in developing the new units, have refined conventional aircraft generator design to include:

1. Elements capable of withstanding higher operating temperatures
2. Greater heat transfer areas to reduce heat flow resistance
3. Design changes to reduce heat losses

Maximum cooling is provided through one of the most unique features of the new units, a "straight-through" air path that allows free air passage under the commutator and through the armature.

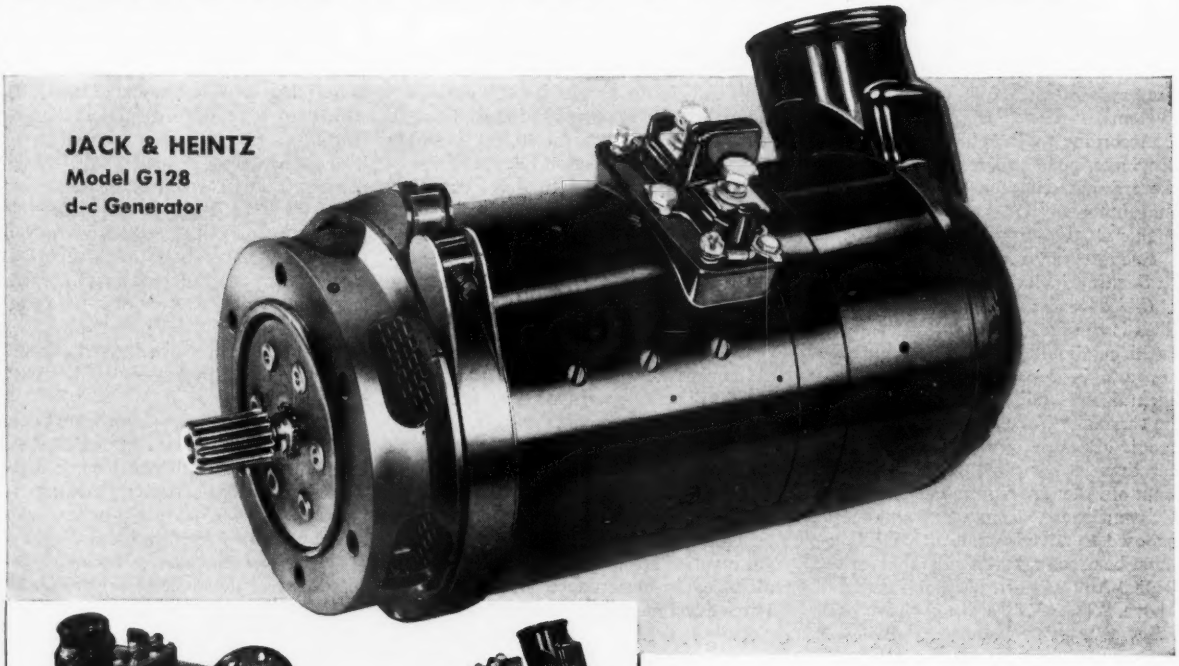
Specially designed blast caps are available to meet specific airframe requirements or to effect reduction in over-all generator dimensions.

JACK & HEINTZ

CLEVELAND 1, OHIO

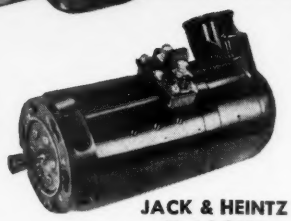
Field Offices: New York City · Washington, D. C. Dayton · Dallas · Los Angeles · Seattle

GENERATORS FOR JETS



JACK & HEINTZ
Model G128
d-c Generator

JACK & HEINTZ
Model G124
d-c Generator



JACK & HEINTZ
Model G123
d-c Generator

DESCRIPTION	MODEL G123	MODEL G124	MODEL G128
Basic specifications*	MIL-G-6162	MIL-G-6162	MIL-G-6162
Ampere rating at 30 v	300	400	400
Speed range (rpm)	3000-8000	3000-8000	3100-8000
Cooling air pressure (in. of water)	6	6	12
Engine mounting pad	AND-20002	AND-20006	AND-20002†
Length (in.)	13⅞	13$\frac{5}{32}$	14¾
Diameter (in.)	6½	8	6½
Weight (lb)	64	81	68
Overhung moment (in.-lb)	360	430	450

†*Equipped with Quick-Attach-Detach mounting flange.*

J&H looks to the Future

In addition to the d-c generators described, several new a-c generators will be available soon. This group of alternators includes:

G181-1—a 30-kva, 4800 to 7200-rpm air-cooled unit

G281—a 40-kva, 6000-rpm air-cooled unit

G186—a thermal-lag unit with a magnetic amplifier regulator

G190—an oil-cooled unit

G180—an air-cooled 6000-rpm unit developing 120 kva with air pressure of 6″ water, 160 kva with 12″ water.

J&H engineers will be glad to work with you in developing aircraft electrical, mechanical or hydraulic devices to meet your special requirements. Write Jack & Heintz, Inc., 17632 Broadway, Cleveland 1, Ohio.

*Military specification numbers as used herein are for purposes of product identification only and do not necessarily imply specification conformity.

Rotomotive EQUIPMENT

© 1953, Jack & Heintz, Inc.

Aircraft Generating Equipment—a-c and d-c—including Control Systems and Components • Electric Starters • Actuators and Special Aircraft Motors • Custom-built Commercial Motors • J&H Eisemann Magnetos

thrust ratings, and the company reports that it is developing a pneumatic starter. An air turbine type, this new starter will be capable of quick-starting jet engines with ratings in the vicinity of 10,000 lbs. thrust.

Although initially "starter specialists," Jack & Heintz design engineers have become recognized as authorities on other electrical aircraft accessories, notably generators (a.c. and d.c.), inverters, motors, actuators, and control systems.

According to Joseph Mulheim, Chief Engineer, good progress is being made toward shattering the "thermal barrier" and other obstacles to higher speed, higher altitude aircraft.

Such developments as can be reported at this time include:

G75 Alternator (A.C. Generator).—This is the first successful water-cooled (utilizing liquid vaporization) alternator and is designed as an "environmental-free" unit. The alternator may be thermally isolated from the environment. Because of an efficiency of better than 93 per cent, only 3.5 lbs. per hour of water are required at rated load. Conventional alternators, inherently exposed to adverse ambient conditions, must be correspondingly derated for the 35,000- to 60,000-ft. altitude range and above. The G75, a three-phase, 400-cycle, 12,000-r.p.m. unit, rated at 12 kva. can deliver an overload condition of 16 kva. and maintain satisfactory cooling while operating at extremes of temperature and altitude.

A.C. Generators.—Jack & Heintz is currently engaged in the development of a.c. generators and a.c. control systems. Generator ratings range from 15 to 120 kva.

F137 Inverter (Motor-Generator).—This unit is the first of its volt-ampere rating to have completed Air Force altitude cycling tests for 50,000 ft. and to be given a production release by the military. Capable of 1500 va. output at 50,000 ft. and a 20°C. ambient temperature, the 115-volt, 400-cycle, single-phase inverter virtually frees aircraft of such critical high-altitude inverter problems as overheating, insulation breakdown, and excessive brush wear.

Commenting further on inverter developments, Mulheim reports that the F137 will be followed shortly by production of the F147, capable of 2,500 va. at 50,000 ft. This unit has been granted production release by the Procurement Division of the Air Materiel Command. Jack & Heintz is also pioneering the design of an "environment-free" 2,500-va. inverter for operation at still higher altitudes in accordance with an Air Force development contract.

D.C. Generators.—A series of d.c. generators—G123, G124, and G128—developed at Jack & Heintz (now under military test) promises to overcome the inadequacy of existing d.c. units. Today's generators are designed for operation on reciprocating engines with continuous duty at 6,000 r.p.m.; jet engines, however, require continuous operation at 8,000 r.p.m. The G123 supplies 300 amp.; the G124 supplies 400 amp. The G128 is a model of the G123 which incorporates special installation features. The G128 provides an overload rating that is made possible by special internal cooling of the commutators. Utilizing blast air from the jet engine, this cooling technique enables the G128 to carry more than double the current density of present generators at less than two-thirds the brush temperature.

All three models are termed "true" 8,000-r.p.m., continuous-duty, d.c. generators.

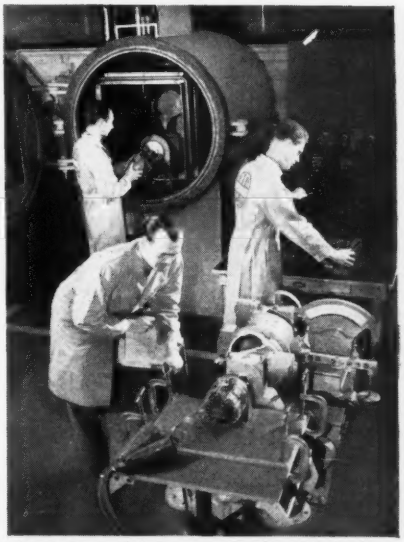
Other Developments.—Aside from these achievements, Mulheim indicates that substantial progress is being made with electric-hydraulic actuators, small turbine starters for jet assist units, and turbohydraulic power packs.

Commercial Aviation.—It should be noted that, although designing primarily for the military, Jack & Heintz devotes

Piasecki helicopter corporation

MORTON, PENNSYLVANIA

U. S. Motors' Production Testing Laboratory where aircraft motors undergo series of critical tests.



View in Research Laboratory showing altitude chamber for simulating actual operational conditions.

Building high frequency, induction type aircraft motors is no new venture for U. S. MOTORS. More than 10 years ago, U. S. MOTORS pioneered production of this new type of motor, having designed and built motors tested by the U. S. Air Force for use in planes then under development. By using experience gained in industrial motor manufacture since 1908, U. S. MOTORS was able to produce aircraft motors that were immediately acceptable by the aircraft industry. We early developed motors with increased power from reduced weight and introduced new design features that have proved most adaptable to aircraft service. As pioneers in this division of the electrical industry, U. S. MOTORS has gained know-how through endless research, testing and close cooperation with aircraft engineers and component manufacturers. This ripened experience is an asset of inestimable value to you.

Facilities for production of U. S. aircraft motors have grown to mass proportions. Each order is specially engineered to exact specifications mutually agreed upon by user and maker. As a dependable source for aircraft motors, you'll find U. S. MOTORS completely in accord with your ideas and requirements.

View of U. S. Motors' Winding Department in Aircraft Division.

U.S. HIGH FREQUENCY INDUCTION TYPE AIRCRAFT MOTORS

U.S. ELECTRICAL MOTORS Inc.
AIRCRAFT DIVISION
BOX 2058, LOS ANGELES 54, CALIF. OR MILFORD, CONN.

MAIL COUPON FOR BULLETIN

REQUEST FOR U. S. AIRCRAFT MOTOR BULLETIN

U. S. ELECTRICAL MOTORS INC.
Box 2058, Los Angeles 54, Calif. or Milford, Conn. AER-12

Name_____
Company_____
Address_____
City_____ Zone_____ State_____

DEPARTMENT OF TECHNOLOGY BUFFALO PUBLIC LIBRARY

engineering talent to the modification of its military products to meet the specific maintenance and service life needs of the commercial air lines. Working in conjunction with air-line engineering and maintenance personnel, Jack & Heintz has already adapted its starters, generators, and inverters to air-line use.

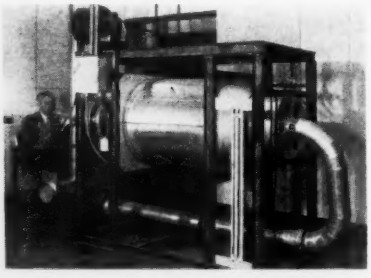
JOHNS-MANVILLE SALES CORPORATION

New York, N.Y.

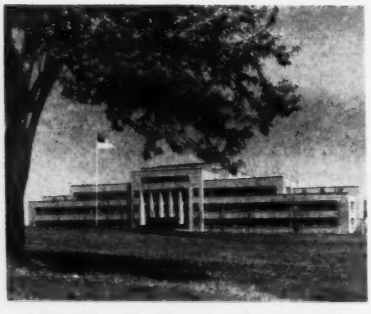
Most men in the aviation industry are familiar with Johns-Manville products. However, many in the industry may not have an intimate knowledge of the special services that Johns-Manville offers.

Of these, the facilities of the J-M Research Center are most important. Here are scientists and engineers who are workng constantly on the problems of insulations for jet engines and materials for the protection of air frames, gas tanks, and accessories against the temperatures created by high-speed flight. They also are doing important work in developing improved seals, packings, and gaskets to meet the requirements of new aircraft designs.

These men have specialized knowledge and the advantage of laboratory equipment especially built for aviation studies. They also have the help of colleagues working in related fields and this association is often a major help in reaching solutions.



This apparatus determines the conductance jet-engine insulation blankets under simulated service conditions.



Johns-Manville Research Center at Manville, N.J., where new and improved materials for the aviation industry are constantly being developed.

In other words, the Johns-Manville Research Center is three-dimensional evidence of a policy that one of the company's founders stated in this way: "We promise and claim less than many others, but shall endeavor as heretofore to furnish the best materials of the kind and to make every resource available for their improvement."

CORYDON M. JOHNSON COMPANY, INC.

Bethpage, L.I., N.Y.

The Corydon M. Johnson Company, Inc., has been actively associated with aviation and its allied fields for more than 22 years. Founded in 1931 by Corydon M. Johnson, President of the company, services were directed toward engineering phases of aviation, including the preparation of engineering drawings, tracings, design data, and technical publications.

In 1941, the Johnson Company extended operations to include creative printing and complete advertising services. This expansion, coupled with technical experience, offers service styled specifically to meet Long Island's increasing technical and commercial demands. Firms such as Grumman, Kenyon, Sperry, Fairchild, Republic, Arma, Telephonics, etc., are continually being served in their need for drawings, reports, handbooks, brochures, advertising, sales literature, catalogs, charts, training programs, and research.

The Johnson Company has geared its organization to continue meeting accelerated printing and advertising needs of Long Island's industry and business. With complete creative and production facilities housed under one roof, the Johnson Company offers its clientele a complete package—from copy to printed product. The company employs 200 trained personnel—engineers (aeronautical, mechanical, and electronic), draftsmen, technical writers, illustrators, artists, photo technicians, typographers, lithographers, and printers.

As an added service, the company has published for the past 6 years the "Corydon M. Johnson Report," a monthly digest-type of newsletter covering significant happenings and developments on Long Island, circulated privately to approximately 4,000 key executives.

EARLE M. JORGENSEN COMPANY

Los Angeles, Calif.

Long before U.S. entry into World War II, when production for defense began to take its place as the major part of industrial activity, the need became evident for readily available stocks of aircraft quality steels from which airframe manufacturers and subcontractors could draw. The Earle M. Jorgensen Company immediately began to build up such stocks and following Pearl Harbor was one of the several distributors throughout the country appointed by the Government to carry earmarked aircraft stocks. With plants in Los Angeles, Oakland, and Houston, the company was in a position to serve the major aircraft producing areas of the west and southwest. In 1950, a new plant was opened in Dallas, specializing in aircraft material, and construction of another in Tulsa will be completed about the end of this year. Steel stocks consist of alloy and stainless steels meeting aircraft specifications, as well as a complete line of carbon and tool steels, which find many applications in the "nonflying" end of aircraft production. All Jorgensen plants also maintain complete stocks of aluminum. In both steel and aluminum, stocks are established in line with recommendations of the National Aircraft Standards Committee, and virtually all items on the Committee's list are available for immediate delivery. Jorgensen also acts as a mill agent and can develop prompt shipment of items not in warehouse stock.

WALTER KIDDE & COMPANY, INC.

Belleville, N.J.

Safety in flight has always been the major consideration of airplane designers, manufacturers, and owners—and fire is a prime safety factor. It makes no difference whether the plane is a single seater or a huge passenger air liner; effective means for extinguishing a blaze must be available for immediate use.

Walter Kidde & Company, Inc., for years has been the major supplier of fire-extinguishing equipment for civilian, commercial, and Government airplanes. Practically every American-made plane flying today has some Kidde equipment aboard.

The company is best known for its continuing experiment in fire-extinguishing systems for nacelles. These systems usually employ a prime and a reserve charge of carbon dioxide or CB. They are engineered so that the pilot can actuate the system and route the fire-smothering agent to any nacelle or auxiliary compartments such as the cabin heater space or the baggage locker.

The company's carbon-dioxide and/or water extinguishers frequently are found in cockpits, passenger compartments, and galleys of a host of American planes. A similar situation exists on the ground, where Kidde carbon-dioxide portables and wheeled units

NAME IT...
and you can have it!

Need any part or all of a pneumatic system? Just name it and chances are we can supply it.

If you're still in the planning stage, be sure to call on our engineering department. Put their years of experience to work for you. It can probably save you time and money.

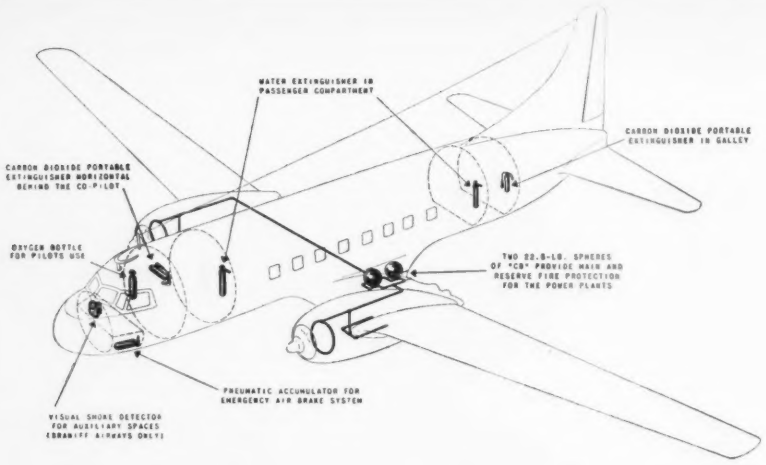
The nameplates before you are from only a few of the pneumatics parts rolling off the Kidde production line. Kidde pneumatic components are now being used on almost every make and type of plane.* Their basic designs are easily adjusted to just about any pneumatic need.

Write today for full information.

*F2Y1, B29, B36, B47, B50, B52, B57, DC4, DC6, DC7, C124, C119, Convair 340, C123, F94, F7U3, F4U7, AU1, F3D, F9F, AD4, P2V, P4M, P5M, F2H, F3H, F101, F100, FJ2, F89.

Kidde

Walter Kidde & Company, Inc.
1211 Main Street, Belleville 9, N. J.
Walter Kidde & Company of Canada, Ltd., Montreal, P. Q.


WATER EXTINGUISHER IN PASSENGER COMPARTMENT
CARBON DIOXIDE PORTABLE EXTINGUISHER IN GALLEY
CARBON DIOXIDE PORTABLE EXTINGUISHER HORIZONTAL BEHIND THE CO-PILOT
OXYGEN BOTTLE FOR PILOTS USE
TWO 22.5-LB. SPHERES OF "CO2" PROVIDE MAIN AND RESERVE FIRE PROTECTION FOR THE POWER PLANTS
PNEUMATIC ACCUMULATOR FOR EMERGENCY AIR BRAKE SYSTEM
VISUAL SMOKE DETECTOR FOR AUXILIARY SPACES (BRANIFF AIRWAYS ONLY)

KIDDE EQUIPMENT IN CONVAIR "340"

stand guard during refueling and engine starts.

Presently, Kidde is devoting substantial effort to the development of pneumatics for airplanes. While its air compressor, pressurized systems, and pneumatic gun charger have been limited to military aircraft to date, experiment and research indicate that pneumatics soon may be used as primary, rather than emergency, power sources for control surfaces and mechanical equipment on both commercial and military airplanes.

Kidde has also been active in the development of aircraft smoke and fire detectors and as a supplier of metal storage cylinders for oxygen and compressed air.

KOLLSMAN INSTRUMENT CORPORATION

Elmhurst, N.Y.

The year 1953—the 50th Anniversary of Powered Flight—holds added significance for Kollsman Instrument Corporation, marking its 25th year as one of the world's foremost manufacturers of precision aircraft and optical instruments and systems.

The early history of Kollsman is closely associated with pressure instruments. These are built around metal diaphragms of specialized Kollsman design and construction. The extreme pressure-responsiveness of these diaphragms made possible the first sensitive altimeter. Twenty times more sensitive than any of its predecessors, this new instrument in 1929 contributed importantly to the first fully blind flight in history.

Later, pacing the continuously increasing speeds, ranges, and altitudes of flying craft, Kollsman engineered the sensitive airspeed indicator, true airspeed indicator, Mach airspeed indicator, machmeter, and numerous other sensitive pressure instruments. The machmeter, for instance, was mounted in the Bell X-1, the first aircraft to crash through the sound barrier.

With today's trend in aircraft instruments going from indication toward automatic control of flight, the electronic arts have been drawn upon to provide the bridge between indication and control. Kollsman's electromechanical units translate mechanical indication into electrical signals that give intelligence to an automatic control or to a visual indicator. Included in this group are angle-of-attack transmitters, synchro-indicators, transducers or varying resistance pickups, synchrotel pickups, radiosonde modulators, altitude and airspeed controllers, tachometer indicators, cabin pressure controls, and others.

As a corollary to its work in this field, Kollsman has developed a line of special-purpose motors and electrical units. Currently, a wide variety of these motors, generators, circutrols, and teletorques are employed in electronic equipment, in servo systems, in designs calling for power or potential sources of sinusoidal wave form, as control components in electronic circuits, and in remote indication systems.

In the field of optics, Kollsman designs and manufactures numerous high quality navigation devices. One of these, the periscopic sextant, has eliminated the astrodome in long-range aircraft and has made important safety contributions. Widely known are the Kollsman Sard binoculars. Kollsman is also producing optical systems and components used in the latest types of computers, automatic pilots, bombsights, and gun sights, as well as a variety of special purpose prisms, lenses, and reticles.

Radio Communications represents the newest field to receive the attention of Kollsman engineers. In this area, the company designs, develops, and produces systems and equipment in radio navigation, radar, telemetering, direction finding, missile radio, radiosonde, and aircraft approach and landing.

LAVELLE AIRCRAFT CORPORATION

Newtown, Bucks County, Pa.

Lavelle Aircraft Corporation was incorporated in 1940 for the purpose of producing high-quality precision sheet-metal parts and assemblies for aircraft. During World War II, employment reached a peak of nearly 400, and products produced, principally of aluminum alloy, included fin assemblies, ladders and junction boxes for the C-46, GCA radar reflectors, air-borne reflectors, tow reel kits, and many other aircraft parts.

During the postwar period, production continued on aircraft and radar parts, although on a reduced scale. Stabilizer assemblies for commercial aircraft, oil tanks, engine mounts, radar reflectors, and shelters were typical. The development of the jet engine provided Lavelle with an opportunity to apply its varied welding experience to this field. Combustion housings, liners, and calibrating and testing nozzles are typical of many parts produced during this time.

When the outbreak occurred in Korea, Lavelle was prepared with equipment, man power, and "know-how" and has produced welded stainless-steel assemblies such as tailpipes, shrouds, nozzles, heat exchangers, and related parts. Precision aluminum-alloy assemblies such as radar reflectors, jet-engine cowling, nacelles, as well as steel tube engine mounts, are also currently in production.

While much of production has been to customer drawings, Lavelle engineers have designed such units as radar reflectors and shelters to specifications and participate as required in all projects.

Thus, in the 13 years since incorporation, Lavelle production has changed from almost 100 per cent aluminum-alloy construction to about equal percentages of stainless steel and aluminum alloy, reflecting the engineering trend of the period.

LEAR, INCORPORATED

Los Angeles, Calif.

Although the Company's first commercial contribution was a highly successful automobile radio whose vibrator power supply principle is still widely used in many different fields, Mr. Lear quickly turned his fertile inventiveness

B.F. Goodrich offers new way to cut equipment, add to landing safety

AT LAST, something is taken *off* the airplane! B. F. Goodrich takes out the inner tube—and pounds are saved with B. F. Goodrich tubeless tires.

First announced for combat jets like the Navy's Grumman Cougar, the new BFG tubeless airplane tire gives safer high-speed landings and take-offs, cuts weight, simplifies assembly and maintenance.

Like the famous B. F. Goodrich Tubeless Tire for passenger cars, introduced five years ago, the new airplane tire has a patented inner lining that's part of the tire itself. There's no tube to go flat—no tube to bunch up or shift during landings and take-offs.

Because the inner tube is eliminated, the new BFG tubeless airplane tire is lighter. Instead of tire and tube, there's only one unit to mount. Only one unit to warehouse, too. There's less checking of inflation pressure because the special lining retains air much longer than conventional tubes. Loss of air around the rim is prevented by ridges molded on the outer side of the tire.

Another B. F. Goodrich first in aviation, the new high pressure tubeless tire for combat jets is the latest example of BFG's leadership in rubber research and engineering.

Send this coupon for blueprint showing cross section of the B. F. Goodrich tubeless tire, how it is mounted easily on standard wheels, other advantages. *The B. F. Goodrich Company, Aeronautical Division.*

B.F.Goodrich
FIRST IN RUBBER

The B. F. Goodrich Company
Dept. A-93, Akron, Ohio
Send free blueprint of the BFG tubeless tire.

Name .....
Title .....
Firm .....
Address .....
City ..... Zone ... State .....

DEPARTMENT OF TECHNOLOGY BUFFALO PUBLIC LIBRARY

to the radio needs of the private pilot. He met the problem head on by designing and building in commercial quantities what many considered the first practical radio receiver to serve the needs of the man who flies his own plane.

As the fledgling organization grew, there followed many famous "firsts."

Blazing new trails, Lear supplemented its interest in the small plane pilot by addressing its electronic skills to the highly specialized and even more exacting needs of the air lines. In 1940, Chicago and Southern Airlines adopted Lear's ADF-7 automatic direction finder immediately following certification of this equipment by the Civil Aeronautics Administration.

In 1940, the Company developed and introduced the Learmatic Navigator—an instrument providing pilots with straight-track navigation, utilizing any radio station available. For his creation of this instrument Mr. Lear was awarded the Frank M. Hawks Memorial Award.

Development of Lear's "Fastop" clutch led to far-reaching applications in aircraft at a time when the highly efficient control features of this device were vitally needed for World War II production. Lear "Fastop" clutches went into motors used for positioning cowl flaps on B-24's and B-29's as part of a complete system utilizing Lear-designed flexible power shafting and screwjacks. Marking the beginning of Lear's large-scale electromechanical business, this type of clutch subsequently became standard for nearly all aircraft electric motor-driven equipment.

Wartime expansion of the company's developmental activities necessitated parallel expansion of its manufacturing facilities. In 1945, the Company moved its administrative headquarters and most of its activities to its present large plant at Grand Rapids.

After World War II, the entry of the aircraft industry into the development and production of the new jet-propelled aircraft created many radically different actuation problems. To meet these unprecedented requirements, Lear developed and furnished, in 1948 and 1949, a number of new, highly specialized electromechanical products such as jet-engine air inlet shut-off controls, aileron bungee actuators, heat valve actuators, and new-type electric motors.

In 1948, Lear acquired the business and assets of the Romec Pump Company in Elyria, Ohio, which then became the Lear-Romec Division of Lear, Inc. Following this acquisition, Lear, in 1949, strengthened that division's existing products and developed a number of new pump and allied products for aircraft and special industrial use and is today the largest supplier of water-injection pumps for piston engines and pressurization-desiccation equipment for air-borne radar.

Early in 1949, following the decision of the CAA to convert the federal airways system from the low and middle frequency bands to the more serviceable very high frequency (VHF) band, Lear completed the development of certain new products that constituted its advanced line of VHF navigation and communications equipment.

Climaxing an intensive development conducted in coordination with the U.S. Air Force, Lear, Inc., developed and furnished, in 1949, the F-5 autopilot and automatic approach coupler for jet aircraft and received production contracts for these items. The F-5 autopilot system has already fully demonstrated its worth in critical tactical flight missions and is today in volume production along with the Lear VGI (vertical gyro indicator), a precision attitude indicating instrument that is being supplied by Lear for production installation on jet fighters, bombers, transports, and helicopters. The company's many contributions to automatic flight control were dramatically underscored by receipt of the 1949 Collier Trophy.

In 1951, the Lear L-5 autopilot, a commercial version of the F-5 military autopilot, was offered for air-line and corporation aircraft use. In 1952, a test installation of the L-5 autopilot was made in a Slick Airways cargo DC-6A. On the basis of its performance in that plane, the CAA granted its approved type certificate to the L-5 autopilot for use in DC-6A cargo planes and DC-6B air-line passenger planes.

The Lear L-2 autopilot, designed for light planes and smaller twin-engined aircraft, was offered to the aviation public late in 1949.

THE LIQUIDOMETER CORPORATION

Long Island City, N.Y.

The pioneering spirit exemplified by Clarence A. deGiers as one of the country's first fliers, has been continued by The Liquidometer Corporation, which he founded more than 30 years ago.

The first Liquidometer remote reading aircraft fuel gage was the hydraulic type, which was used on the first air-mail planes and many early military models.

The advent of larger aircraft necessitated a fuel-gage system utilizing one indicator for several tanks. Liquidometer was the first to introduce such a system, which included such original developments as compensation for voltage fluctuations, characterized tank units, totalizing, fuel temperature compensation, fuel density compensation, and combination indicator-selector switch units.

In researching capacitance fuel gaging systems since 1940, Liquidometer introduced many "firsts," among which were characterized tank units to provide uniform dial graduations, fuel dielectric compensation, fuel density compensation, hermetically sealed indicator-power unit combination, subminiature coaxial cable connectors effecting large weight reductions in interconnecting wiring, systems not requiring coaxial cable, weight and/or volume indication in the same system, tubeless power unit, and tubeless indicator-power unit combination, to name but a few.

Liquidometer's extensive research program assures a continuance of "firsts" in fuel gaging and other aircraft instrumentation.

LOCKHEED AIRCRAFT CORPORATION

Burbank, Calif.

Air travelers who today speed across the Atlantic in luxurious Super Constellations, with no more concern than the 5:15 commuter to Yonkers, seldom realize what it took to give them their miracle of smooth, safe flight—what went into the 50-ton package of aeronautical science that spans the sea between breakfast and teatime.

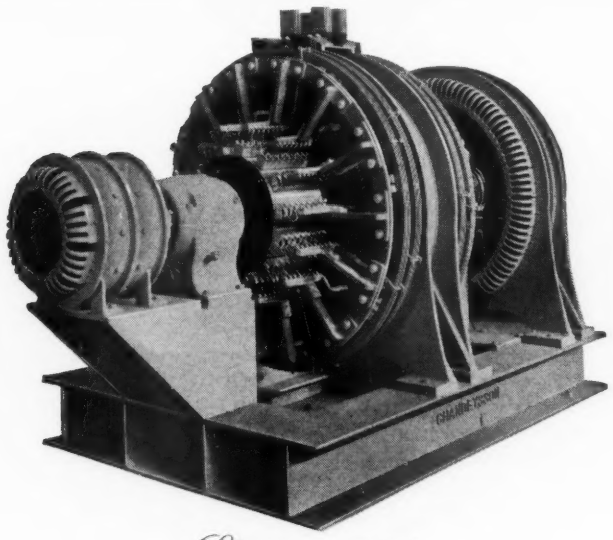
The casual transatlantic commuter may be unaware that 25,000 Lockheed aircraft have preceded this Super Constellation in the air.

But those first 25,000 planes are like 25,000 stair steps of engineering progress. In time, they could be stair steps to the moon. . . ?

In the 21 years of Lockheed operation under the company's present management, aircraft bearing the winged-star emblem have introduced a string of engineering achievements probably unequaled by any other air-frame manufacturer. The list of Lockheed engineering "firsts" is divided into three main groups of developments—for commercial planes, for military planes, and for manufacturing.

Actually, Lockheed aeronautical innovations date back to 1912 when Allan and Malcolm Laughead—whose name was later changed to Lockheed—started building flying machines in San Francisco and Santa Barbara, Calif. They tried such things as the triple rudder, unwittingly setting the trademark for later Constellations; the folding wing on the S-1 sports plane of 1919; and the monocoque fuselage of molded plywood.

But Lockheed's major growth, both in volume of engineering and scientific research and in quantity of product, has come in the last two decades, under Hall L. Hibbard, Vice-President—Engi-



Since 1904 . . .

HELPING PROVIDE
THE POWER BEHIND AIRPOWER

Chandeysson MOTOR-GENERATORS

. . . low-cost, high-efficiency power conversion for plating and anodizing

Original Chandeysson units built almost half a century ago continue to give flawless service today. One reason for this sturdiness and dependability is the extra overload capacity built into Chandeysson Motor-Generators. They can carry loads far in excess of their rated capacity for long periods of time without damage.

Another reason for the growing acceptance of Chandeysson units over the years is their unusually high operating efficiency. In aircraft plants, where you may need extra capacity to meet emergencies, Chandeysson Generators will never let you down.

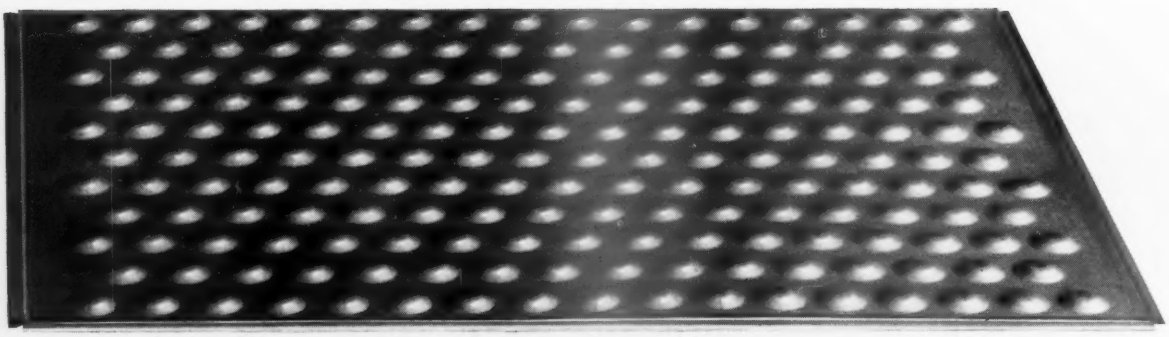
For more information, please write:

CHANDEYSSON ELECTRIC COMPANY • 4054 Bingham Avenue, St. Louis 16, Missouri

537

6

AN IMPORTANT NEW GEOMETRY FOR



HEAT EXCHANGERS

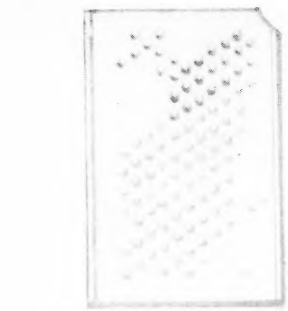
As the performance ceiling of modern aircraft continues to rise, extremes of temperature and pressure in heat generating and in heat exchange equipment create new and challenging problems.

Today's emphasis on heat transfer systems gives particular significance to Janitrol's most recent advance in this field: a new type of "dimple plate" construction which improves efficiency, saves weight, increases strength, simplifies manifolding, and opens a whole new geometry of design.

A complete heat exchanger can now, in effect, be laminated from identical, paper-thin stampings like that shown above. The sheets are welded in pairs, face to face, creating continuous passages for flow of air or liquid—each passage being at right angles to the next, and all passages manifolded in a simple economical design. The indentations increase rigidity of the assembly, facilitate fabrication, and at the same time accelerate heat transfer by creating a desirable turbulence in the flow.

Observe that this new lamination technique permits envelope configurations practically without limit. Now, a high efficiency heat exchange system can be squeezed into spaces previously unusable, and duct or piping connections greatly simplified.

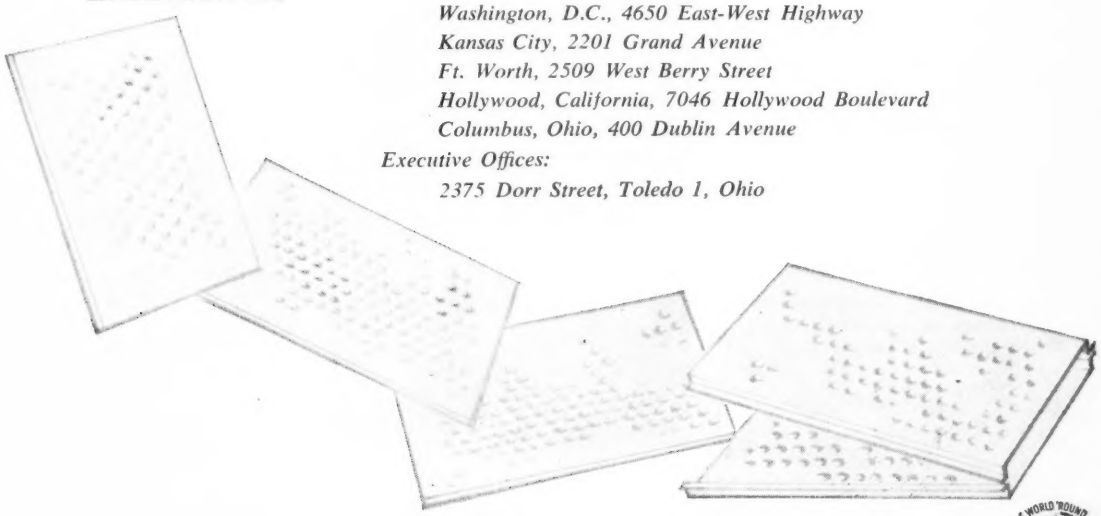
If your heat exchanger problems involve increasingly high temperatures, high pressures, or special space restrictions, you'll do well to investigate this new Janitrol development. In fact, whatever your aircraft combustion problems, your Janitrol representative can place at your disposal Janitrol's thirty-seven years' experience in the manufacture of combustion equipment.



Janitrol®

37 years experience in combustion engineering

National Sales, Engineering, Production Headquarters,
400 Dublin Avenue, Columbus 16, Ohio
District Engineering Offices:
New York, 225 Broadway
Washington, D.C., 4650 East-West Highway
Kansas City, 2201 Grand Avenue
Ft. Worth, 2509 West Berry Street
Hollywood, California, 7046 Hollywood Boulevard
Columbus, Ohio, 400 Dublin Avenue
Executive Offices:
2375 Dorr Street, Toledo 1, Ohio



AIRCRAFT-AUTOMOTIVE DIVISION, SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

KNOWN THE WORLD 'ROUND

neering, Clarence L. Johnson, Chief Engineer, and an engineering team now numbering more than 3,000 men and women.

In commercial transport channels, Lockheed has provided numerous innovations that remain standard today.

Fuselage pressurizing is a field of intense Lockheed interest. The XC-35 was the first successful fully pressurized transport airplane. Its lessons helped make the Constellation the first pressurized commercial transport.

Wing flaps were an early Lockheed development. The company perfected and first used commercially (on the Model 14) the Lockheed-Fowler flap, forerunner of equipment in world-wide use now.

One of the present company's earliest successes was the Electra, perhaps the first all-metal bimotor transport, which pioneered in use of a twin tail for stability and control.

Lockheed also introduced commercially the first retractable landing gear, on the Altair, and used the first single-spar type of all-metal wing.

Always in quest of increased transport speed, Lockheed gave the world the first 300-m.p.h. passenger air liner when it built the Constellation.

The Constellation series entered its 10th year of service in 1953, and in the new Super Constellation Lockheed foresees many more years of air-transport progress. The Super Constellation is the first transport to fly with turbocompound engines. It offers a drastically different concept of passenger accommodations—multicompartmentation, for privacy and for varied classes of transportation (first to third class) in the same airplane; quick convertibility from maximum luxury to tourist service; and subtle use of interior decorating to give passengers the utmost in flying pleasure.

In the production of military aircraft, Lockheed engineers have turned out an impressive list of "firsts," many of which have become standard. Here are a few:

First U.S. twin-engined fighter (P-38).

First U.S. twin-boom fighter (P-38).

First tricycle gear fighter (P-38).

First production turbosupercharged fighter (P-38).

First completely power-booster-controlled commercial airplane.

First fighter with power-boosted ailerons.

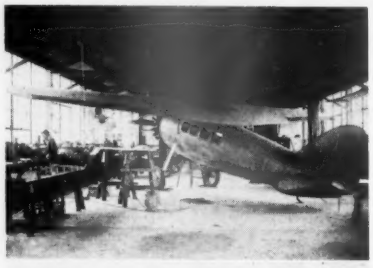
First use of a compressibility dive flap.

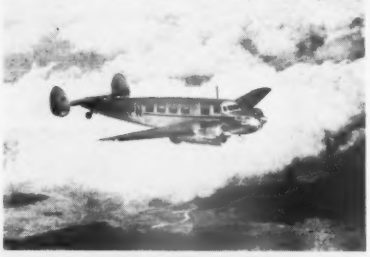
First fighter with a pressurized flight station (P-49).

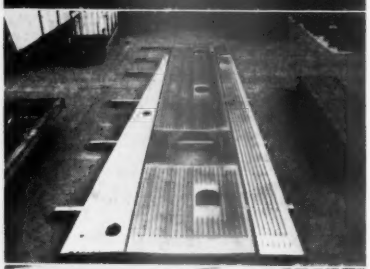
First fighter equipped to find its target by radar.

First production jet with afterburner.

First fighter to use a tail-parachute brake.







First fighter armed wholly with internal rockets.

First to exploit the value of radar and high-altitude planes for early warning purposes (WV-1).

(From top to bottom, left) **(1) First final assembly shop of Lockheed planes was a one-room factory. The plane is the first Lockheed Vega. (2) Electra, 1934. (3) Lodestar, 1939. (4) Deceleration parachute popped from the tail of an F-94C Starfire, USAF all-weather radar-equipped jet interceptor. (5) Super Constellation wing sections illustrate new technique in air transport design. Center section shown is the largest single piece of wing ever fabricated. (6) Looking at a 1940 prototype jet engine are *(left)* Hall L. Hibbard (FIAS), Vice-President—Engineering, and Nate Price, Power Plant Engineer.**

First to use turbocompound engines (P2V Neptune).

First tip tanks (P-38), now used on both twin-engined and four-engined types.

In the jet-engine field, Lockheed designed and built a prototype of a twin-spool, high-compression, axial-flow power plant during World War II, unaware that similar secret developments were under way elsewhere. Its basic design is now incorporated in one of this country's most powerful new jets.

In the production field, Lockheed aeronautical and manufacturing engineers have pioneered in application of integrally stiffened structures to aircraft, using the first machined skins, in both military and commercial planes.

Lockheed had the first complete X-ray laboratory for testing structural parts and built the first completely equipped Structures Research Laboratory to pretest both structural components and internal systems. It was also the first to develop and use plastic tooling in production, for savings in money, weight, and fabrication.

Lockheed's imaginative industrial leadership was applied also to personnel, both in testing procedures and in training. The company was first to establish an engineering training adaptation program in World War II to turn civil, electrical, and other engineers into airplane designers.

The achievements of Lockheed airplanes are as impressive as the list of engineering developments. Lockheed craft were the first to fly over both poles; first to be flown around the world solo; first to fly the Pacific west to east (Brisbane to Oakland); first to fly more than 10,000 miles nonstop, without refueling (P2V); first to make an air capture of a submarine; first jet to win a jet air battle (F-80); and first jet to shoot down an enemy visible only by radar (F-94).

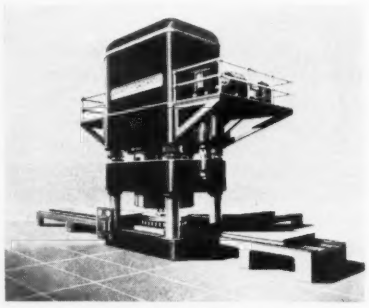
The speed records that Lockheeds have broken—or still hold—would fill a book.

The roster of Lockheed "firsts" is perhaps a fundamental reason why, in this 50th year of powered flight, neither sun nor moon ever sets on an air-borne Lockheed wing.

LOEWY-HYDROPRESS, INC.

New York, N.Y.

Lowey-Hydropress, Inc., a pioneer in plastic metal forming, is a major contractor in the USAF Heavy Press Program.



Visualization of a 6,500-ton capacity Marform rubber pad press for metal forming, designed and being built by Loewy-Hydropress, Inc., for The Glenn L. Martin Company.

Super heavy hydraulic die forging and extrusion presses, from 8,000 to 50,000 tons capacity, as well as Marform and Guerin rubber pad presses up to 15,000 tons capacity, are the answer to the engineers' demand for large one-piece shapes and structures.

These new machines will make possible mass production of air frames for the latest jets.

MARMAN PRODUCTS COMPANY, INC.

Los Angeles, Calif.

Prior to the time Marmam Products Company, Inc., became specialized in developing and manufacturing many different types of clamps and couplings, all aircraft manufacturers had to individually design and tool-up for all of the types they needed for their requirements. During the past decade, the Marman couplings and clamps have gained in acceptance to a point where they are now considered standard in the aircraft industry.

Through specialization in this field, Marman Products Company, Inc., has been able to offer a higher quality product at a lower cost. Through concentrated research and development, the product line was continually improved to keep it abreast of the higher requirements of modern aircraft.

Many interesting applications have been developed, including large couplings for joining tailpipes and afterburners in jet-engine installations.

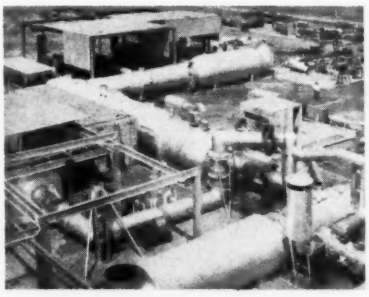
Two recent developments include an all-metal quick disconnect joint, capable of sealing up to 200 lbs. per sq.in. at 1,000°F., and a flexible fuel line coupling for a temperature range from −70° up to 300°F.

MARQUARDT AIRCRAFT COMPANY

Van Nuys, Calif.

Since its beginnings, the qualifications of its leadership and their enthusiasm for the ram-jet engine have uniquely fitted the Marquardt Aircraft Company to bear the title, "Supersonic Propulsion Specialists." Far-seeing officials of the Air Force have cooperated in the creation of the powerful Marquardt Jet Laboratory (see photo), where conditions of ram-jet flight can be simulated on the ground.

Prompt reduction to practice of new ideas has been a guiding principle. As early as 1946, ram-jet engines were designed, developed, and built to demonstrate in actual flight on fighter aircraft the utility of a power plant that has no moving parts. Engines of increased power and speed have been developed and are being flown on several supersonic guided-missile projects.



Marquardt Jet Laboratory.

At the higher flight speeds, attractive amounts of power can be developed by ram-air, and the Company is developing and flying a series of missile and airplane accessory power units that are capable of pumping hydraulic fluid and generating electricity with close speed regulation.

The Marquardt Aircraft Company still deals in ideas—is still led by the same talented people. Today, the Company has 1,100 employees, and its well-equipped manufacturing facilities are producing propulsion and accessory power equipment for supersonic flight.

THE GLENN L. MARTIN COMPANY

Baltimore, Md.

With a history almost as old as that of powered flight, The Glenn L. Martin Company's contribution to the advancement of aeronautical science is an impressive and important list of achievements in research and development.

From the patent for the first free-fall parachute to complete weapons systems for today's military requirements, Martin has made important contributions in manned and pilotless aircraft, rocketry, armament, electronics, auxiliary power plants, plastics, and manufacturing techniques, as well as in other fields.

Today's paratroop drops stem from a Martin experiment during World War I when a motorcycle strapped on an airplane fuselage was parachuted to earth, followed within a few seconds by a soldier. The dive-bombing techniques used by the Luftwaffe during World War II are a direct outgrowth of the Martin BM series of aircraft built for the U.S. Navy in the early 1930's, the first successful aircraft of their type.

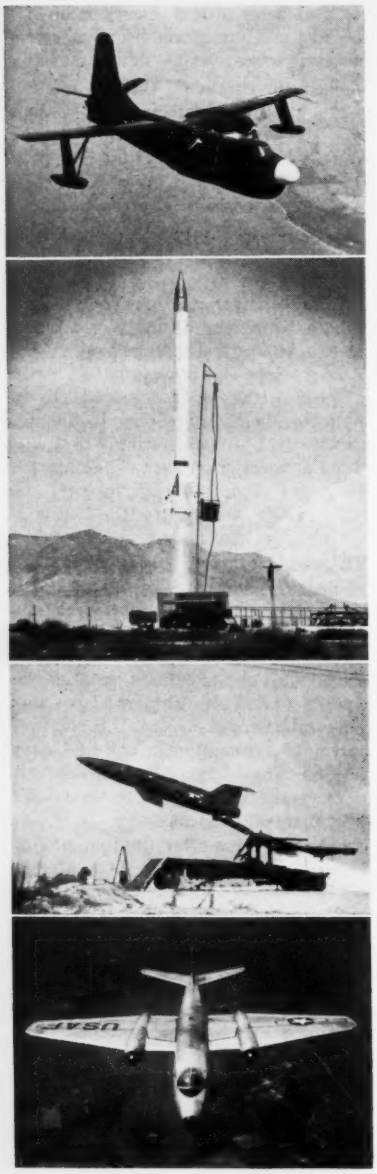
Martin built the first twin-engined bomber, the MB series with which Gen. Billy Mitchell proved that even the mightiest dreadnaughts of the era could be sunk by aerial bombardment. That was in 1921, and one direct result of the experiments off the Virginia Capes was the establishment of the U.S. Navy's Bureau of Aeronautics, which took over the designing of special Naval aircraft to meet the new threat to America's supremacy on the seas.

Within 4 years after the founding of the fledgling company in 1909, Martin had introduced such innovations in aircraft as armor plate to protect the pilot and a two-place trainer. Aerial bombardment was in the experimental stage with a primitive Martin-designed gunsight, and a Martin airplane had made a tremendously long overwater flight—from Newport Bay on the California mainland to Catalina Island, 34 miles away!

Although Martin has built commercial aircraft, the company is known primarily as a military contractor. As such it has delved into many phases of research and development connected with this type aircraft. The power-operated aerial gun turret was an important contribution to military aviation, as was the Mareng ("Mar" for Martin, "eng" for Engineering) cell, a self-sealing bladder-type fuel cell, which prevents leakage and fire when struck by a bullet.

The company has long been one of the world's foremost designers and builders of water-based aircraft, both military and commercial. Pontoons often replaced wheels on many early Martin aircraft, and during the long association with the U.S. Navy which began after World War I many famous seaplanes have been designed and built.

The Martin Clipper ships of the 1930's pioneered transpacific scheduled



(From top to bottom) **(1) USN P5M-1 Marlin. (2) Viking high-altitude research rocket built for the Naval Research Laboratory. (3) USAF B-61 Matador pilotless bomber. (4) USAF B-57 jet bomber.**

passenger and cargo service, making it possible for the first time to fly completely around the world by commercial air lines. Before World War II, Martin had started building the early models of the PBM Mariner series of flying boats, which aided greatly in keeping the Nazi submarines pinned down.

During the late months of the war, Martin began deliveries of the giant JRM 'Mars type of seaplanes, the world's largest military aircraft of their type with a 200-ft. wing span and a gross take-off weight of 82½ tons. Still in service with the Navy, flying between Alameda, Calif., and Honolulu, these big ships are nearing 15,000 hours flight time for each of them.

With the advancement of seaplane research and requirements for military operations, Martin began, after World War II, to develop a replacement for the Mariner—the P5M-1 Marlin, the first airplane specifically designed for anti-submarine warfare. The Marlin can locate a submarine even with only its "snorkel" breathing tube projecting above water and has the armament for its destruction. Further refinements are incorporated in the XP6M-1, a multijet seaplane called the SeaMaster, now being built experimentally.

After World War II, Martin expanded its research, development, and manufacturing programs to include guided missiles, high-altitude research rockets, complete electronic and weapons systems, and many other specialties.

The B-61 Matador pilotless bomber was the first complete weapons system to be built and successfully launched. The Viking rocket, built for the Naval Research Laboratory, holds the world's altitude record for a single-stage rocket, and its telemetering information about conditions in the ionosphere has provided scientists with valuable data about cosmic ray counts, radiation, temperatures, and other mysteries of outer space.

Martin engineers are investigating possible uses of atomic power for many purposes. They have designed many intricate electronics systems for a wide variety of uses and have probed deeply into subminiature equipment, printed circuits, and other advances in that field.

Last summer Martin began delivery to the U.S. Air Force of the first jet night intruder airplane ever manufactured in this country. Known as the B-57, the airplane is an adaption of the basic design of the English Electric Company's RAF Canberra light bomber.

Martin engineers are constantly looking to the future. Designs and developments now in the study stage will not reach fruition for years, but the resultant airplanes will have much greater performance, be more reliable, and be more economical and safer than even the most advanced designs now in service. Truly, the second half-century of powered flight promises things greater than man is dreaming of today.

McDONNELL AIRCRAFT CORPORATION

St. Louis, Mo.

One of the most youthful of the major aircraft companies, McDonnell was founded on July 6, 1939, with only two employees. Today, an experimental-production team of 15,000 occupies the large ultramodern facilities on the edge of Lambert - St. Louis Municipal Airport.

In September, 1941, the U.S. Army Air Force awarded the young company an experimental contract for the XP-67 "Bomber Destroyer," which was first flown on ceiling of 37,400 ft. and a combat range of 2,385 miles. Weighing 20,000 lbs. gross, it carried six 37-mm. cannon.

During the early war years increasing air-frame subcontract work contributed to the company's rapid growth. In January, 1942, the U.S. Army Air Force awarded M.A.C. a contract to produce $15,288,608 worth of twin-engined bomber trainers. This was the first production airplane contract awarded the company.

In January, 1943, M.A.C. received a Navy contract for the XFD-1 Phantom, the twin-jet fighter that became the Navy's first all-jet carrier-based aircraft. After exhaustive engineering studies with various power plants and configurations, the final design emerged with two Westinghouse 19-in. axial-flow turbojet units mounted in wing roots along the fuselage.

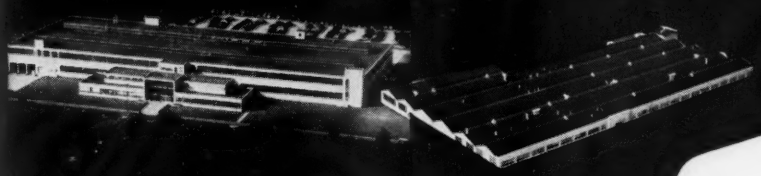
Weighing less than 10,000 lbs., the Phantom had a service ceiling of 37,000 ft. and a range of 1,000 miles. It was armed with four 50-cal. machine guns mounted in the nose.

In a historic flight of July 21, 1946, the Phantom became the first all-jet fighter to operate from a carrier of the U.S. Navy. This flight aboard the "Franklin D. Roosevelt" and subsequent operations of an entire squadron from the U.S.S. "Saipan" proved the basic concepts of this type of operation.

Before the end of World War II, McDonnell had also entered the fields of helicopter and guided-missile development. In May, 1944, the U.S. Navy awarded the company an experimental contract for the XHJD-1 Whirlaway, the world's first twin-engined helicopter.

Developed for an extensive program of rotary-wing flight research, the Whirlaway could carry a crew and ten passengers. Its two, three-blade rotors were partially intermeshing. Either engine could drive both rotors, since an overrunning clutch drive was incorporated in each engine drive. The XHJD-1 could cruise at over 100 m.p.h. with a useful load of 4,000 lbs.

McDonnell's wartime activity in the guided-missile field included production of the KDH-1 Katydid and the RTV-2 Gargoyle. The Katydid was a pilotless target drone powered by a single McDonnell-built pulse-jet engine and designed to train antiaircraft gun crews. The Gargoyle, a self-contained bomb,



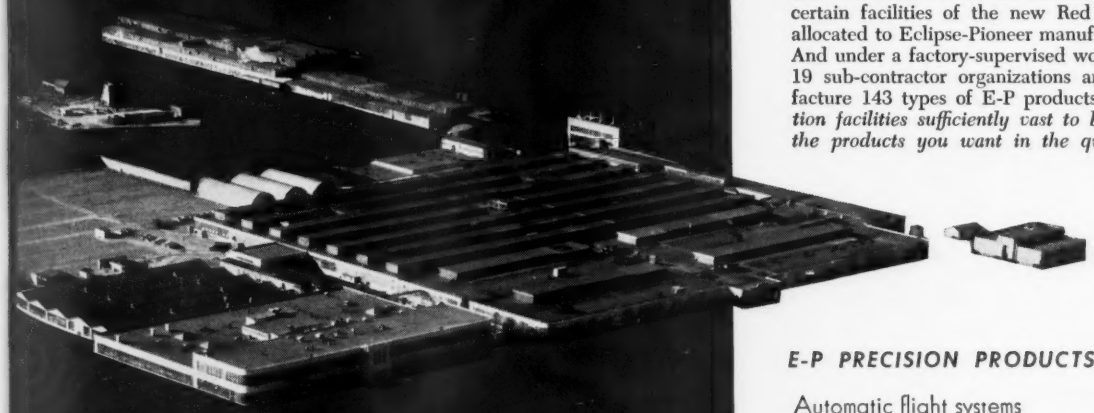
▲ Red Bank Division at Eatontown, N. J.

▲ Utica Division at Utica, N. Y.

◀ Pioneer-Central Division at Davenport, Iowa

Unequalled

experience, manpower and facilities available for post-Korean production.....



Eclipse-Pioneer Division at Teterboro, N. J.

37

That's the number of years we have been in the aviation business—the number of years we have devoted to the creation, development and manufacture of precision products for the aircraft industry. They are years in which we have consistently paced the field with developments of fundamental significance to the evolution of powered flight. *They represent a wealth of practical experience that can play an important role in your post-Korean plans!*

19,142

That's the number of people available to serve you—skilled men and women who are designing, engineering, manufacturing and servicing the products that have developed Eclipse-Pioneer's standing as the world's largest producer of aviation instruments and accessories. *Here is massed manpower ready to satisfy your needs!*

1,444,224

That's the number of square feet devoted exclusively to Eclipse-Pioneer's tremendous operation which, besides our Teterboro plant, includes the complete facilities of the Pioneer-Central and Utica Divisions. But even that is not all the story, for in addition, certain facilities of the new Red Bank Division are allocated to Eclipse-Pioneer manufacturing operations. And under a factory-supervised working arrangement, 19 sub-contractor organizations are tooled to manufacture 143 types of E-P products. *Here are production facilities sufficiently vast to be able to turn out the products you want in the quantities you need!*

E-P PRECISION PRODUCTS INCLUDE . . .

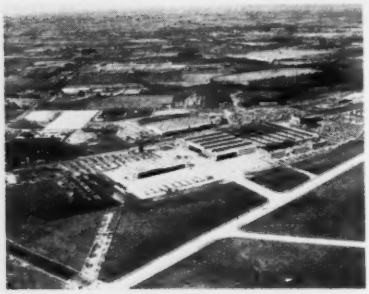
Automatic flight systems
Airplane and engine instruments
Flight and navigation instruments
Power supply equipment
Air-pressurization and ice-elimination equipment
Engine starting equipment
Air turbine-driven accessories
Oxygen equipment
Precision components for servomechanism and computing equipment
Foundry castings

Eclipse-Pioneer

TETERBORO, NEW JERSEY · DIVISION OF Bendix AVIATION CORPORATION

Export Sales: Bendix International Division
205 East 42nd St., New York 17, N.Y.

World's Largest Producer of Aviation Instruments and Accessories



The large, ultramodern facilities of McDonnell Aircraft Corporation on the edge of Lambert-St. Louis Municipal Airport.

is lightweight and armor-piercing and is controlled by radio in flight.

This missile activity laid much of the groundwork for the later establishment of a separate Missiles Engineering Division within the company which is currently working on a variety of classified projects.

In October, 1945, a contract was received from the U.S. Army Air Force for experimental development of the XF-85 Goblin. This unique "parasite" was successfully test-flown at Muroc, Calif., being launched and retrieved from a "parent" B-29 bomber.

Powered by a single J34 turbojet engine, the craft was only 15 ft. in length and weighed a scant 5,600 lbs. It carried no landing gear and was retrieved by hooking on a trapeze suspended from the parent plane.

The famous Banshee series of twin-jet McDonnell fighters went into experimental development in March, 1945. Powered by two J34 engines located in the wing roots, the Banshee has a speed in the 600-m.p.h. class, a range of over 1,000 miles, and a ceiling of over 40,000 ft.

First in the series was the F2H-1. This was followed by the F2H-2, which carried wing-tip tanks, in addition to other design refinements. The F2H-2N was developed as a night-fighter version and the F2H-2P as a photographic airplane, capable of missions at altitudes varying from 50 ft. to 10 miles.

Most recent model is the F2H-3 "all-weather" Banshee, which carries more electronic equipment and greater fire power. The F2H-2 and F2H-2P models were thoroughly battle-tested in the Korean conflict and proved to be extremely reliable under fleet operational conditions.

The McDonnell helicopter engineering activity took another forward stride in June, 1946, with the U.S. Army Air Force experimental contract for "Little Henry," world's first ram-jet helicopter. Weighing only 280 lbs., the helicopter was powered by two 15-lb. ram-jets attached to each end of a single all-metal rotor; it lifted pay loads of more than twice its own weight.

An extensive flight-test program with "Little Henry" laid a basic engineering groundwork for current McDonnell helicopter activity. Convertiplane, an assault transport helicopter, and a cargo unloader helicopter, all experimental projects, are currently in work.

The XF3H-1 Demon, first of an entirely new series of Navy fighters, completed its first flight on August 7, 1951. McDonnell is currently engaged in the production of an undisclosed number of these airplanes.

An Air Force production order was received in September, 1952, for a number of F-101 Voodoo, long-range twin-jet fighters. All details of this airplane remain classified.

Another recent engineering development was the first flight program of the XF-88B, which was fitted up with a single turboprop engine, in addition to its regular twin-jet power plant, to carry out a test program on supersonic propellers. Both of the jets were equipped with McDonnell-developed short afterburners. This program is currently in progress at Langley Field under NACA auspices.

A record backlog of experimental and production contracts in all facets of airplane, helicopter, missile, and propulsion activity has prompted McDonnell to launch an $18,000,000 program to provide complete facilities for aircraft development and manufacture. Included in this program are a new hangar building, wind tunnel, propulsion laboratory, and microwave laboratory altitude test chamber.

MELETRON CORPORATION

Los Angeles, Calif.

Acceptance of pressure actuated switches by aircraft designers and engineers has been a gradual development over a period of about 15 years. Today, the reliability of these sensitive instruments is widely recognized.

The first pressure actuated switches were so complex in character that they were pushed into the background so far as serious study was concerned. Those available could only be obtained from many sources. Today, the whole concept of these instruments is changed. No longer are they considered just a device to flash warning lights. Now, with fuel, hydraulic oil, air pressure, and other systems becoming increasingly complicated, pressure actuated switches operate pumps, open and close circuits, and have assumed a guardianship that makes them essential components of modern aircraft. Meletron Corporation was the first company to provide dependable pressure actuated switches for operational requirements of aircraft, and much of the development has been done by George A. Starbird.

Increased speeds and attendant increases in heat will necessitate construction of pressure actuated switches of materials that can withstand higher temperatures. Like all aircraft manufacturers, Meletron is looking for high-temperature materials. Tomorrow's switches must not only resist greater temperatures, they must also retain, or improve if possible, the accuracy and sensitivity characteristics of present models.

Specialization in this one field, at Meletron, has made it possible to produce, at this single source, a line of switches for any application from zero absolute to 12,000 lbs. per sq.in. gage. Among the principal systems where pressure actuated switches are useful or essential are: engine oil, fuel, radar, missile, cooling, automatic feathering, control surfaces, landing-gear warning, water injection, deicing, and hydraulic-pump systems.

Pressure actuated switches are widely used in engine oil systems. A switch is used to indicate pressure by actuating an indicator mounted in the cockpit of North American's FJ-2 and FJ-3. Another is used on the DC-7 to detect low oil pressure in the supercharger variable-speed transmission.

On AiResearch gas-turbine power unit, a switch is used. This switch detects low oil pressure on the pump of gas-turbine power units and turns on a light located on the engineer's panel. The unit is used to supply pneumatic power for ground operation at this time and is designed for use in the airplane of the future. A similar function is performed by the switch on Lockheed's 1049-B built for the Navy.

A lubricating oil pressure switch is used to sense oil pressure in cabin cooling compressor, a Carrier unit, on the DC-7. This cooling system is used on the ground during refueling, passenger loading, and flight. Switch will indicate by a light on pilot's panel when the pressure is low.

An engine oil pressure sensing switch is used to prevent flow of the water-alcohol mixture to the engine when the engine is not in operation but the injection system has been turned on.

On the Super Constellation, a switch is mounted on the back side of AiResearch cabin air compressor. Compressors are located behind fire walls of No. 1 and No. 4 engines. Switch functions as

CONTINENTAL'S PROOF BOOK

HENRY C. JONES

Chief of Material for Convair's Fort Worth division. His supervision of over 800 people in this department includes responsibility for more than 45,000 items. Over $200,000,000 has been spent by his department during the B-36 production program.

CONVAIR

Consolidated Vultee Aircraft Corporation, Fort Worth 1, Texas

May 7, 1953

Continental Screw Company
New Bedford, Massachusetts

Gentlemen:

At Convair's Fort Worth division, it is the practice to periodically review our 2,196 B-36 subcontractors and suppliers in 38 states.

Recently, we conducted a survey among fastener manufacturers to determine how they were meeting quality standards and delivery schedules. You will be glad to know that the following facts were developed concerning your company:

Screws, Hi-Shear rivets, and other fasteners made by Continental are used throughout the B-36 bomber in varied applications. Our quality control records indicate your screws and rivets have a very high quality rating. There have been no rejections because of faulty workmanship--a factor of supreme importance in this business of aircraft manufacturing.

Continental has been able to maintain deliveries in a very satisfactory manner despite the many difficulties encountered during the past several years. In shortage situations, Convair has been able to receive expedited shipments from you.

In the past year, Convair has been going direct to the manufacturer more and more for purchases on volume items. The direct purchases of both your screws and Hi-Shear rivets show a considerable increase in recent months.

I sincerely hope that the fine relationship between our companies will continue through the years.

Sincerely yours,

Henry C. Jones

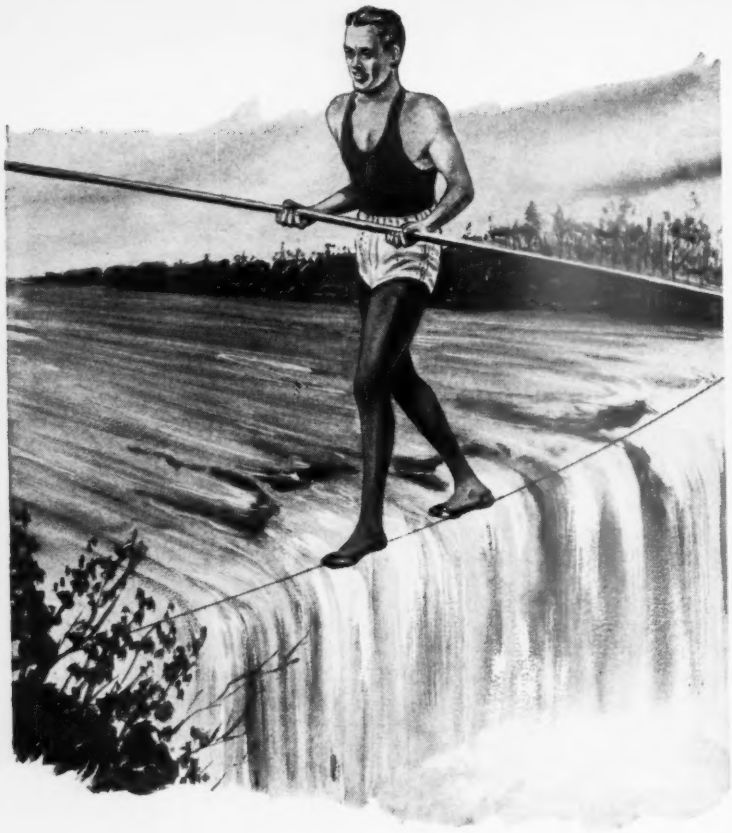
Henry C. Jones
Chief of Material
Fort Worth Division

You too can count on Continental®

CONTINENTAL SCREW COMPANY INC. ★ 1904

Manufacturers of HOLTITE Fastenings For Every Purpose

CONTINENTAL SCREW COMPANY, NEW BEDFORD, MASS., U.S.A.



WE'RE ELIMINATING
CHANCES OF FAILURE

*From zero absolute to 12,000 psi gauge.

Aircraft engineers and designers are seeking a similar goal. Unitedly, they agree: *We must eliminate the chances of a failure.* In this quest to prevent the *chance* of failure in systems, Meletron has perfected pressure actuated switches for every requirement.* With these reliable instruments, we are eliminating chances of failure.

MELETRON® CORPORATION
950 NORTH HIGHLAND AVENUE, LOS ANGELES 38, CALIFORNIA

J. M. WALTHEW CO., Boeing Field, Seattle. THOMSON ENGINEERING SERVICE, 708 Hemphill St., Fort Worth and 732 So. Broadway, Wichita. ROUSSEAU CONTROLS Ltd., 2215 Beaconsfield Ave., Montreal 28, Canada. W. M. HICKS & J. A. KEENETH, 29-27 Forty-first Avenue, Long Island City, New York. JOSEPH C. SORAGHAN & ASSOCIATES, 1612 Eye St., Northwest, Washington 6, D.C.

a low oil pressure warning unit. When oil pressure drops below 30 lbs. per sq. in., a light goes off on engineer's panel, warning him to shut down the compressor.

On the later models of the North American F-86, there are six pressure switches. Four are in the alternate system and are mounted on the under side of the wing center section. Two of these pressure switches energize the alternate system pump when accumulator pressure drops below 2,700 (plus or minus 100) lbs. per sq.in. The other two pressure switches de-energize both transfer valves when alternate system accumulator pressure drops to 650 (plus or minus 50) lbs. per sq.in., thereby automatically returning the control to the normal system. The pressure switches in the normal system are located on the bottom of the wing center section. When pressure in the normal system drops below 650 (plus or minus 50) lbs. per sq.in., the pressure switches close, thereby supplying power to both valves and transferring to the alternate system.

A pressure actuated switch senses the water-alcohol injection pump pressure in water-alcohol injection systems by operating a light in the cockpit. One per engine is located in the engine accessing section in the Douglas DC-6B.

On the Douglas C-124, four switches indicate to the pilot, by four green lights on the panel, that the water injection system is operating. Four switches per aircraft are mounted, one each in nacelle, behind the fire wall.

A switch is used on the Lockheed P2V-4 and the P2V-5 between shut-off valves and pump in the deicing system. One switch is located on each inboard wing panel. The function of the switch is to read the pressure in the line between the pump and the deicing nozzle on the tip tank. If deicing fluid is frozen and cannot pump through, a red light on the pilot's panel remains on, indicating no flow.

A switch is used to sense cabin differential pressure on the Douglas DC-7. It controls recirculating blower for cabin ventilating system during flight.

On Lockheed's YC-130, four switches per aircraft are mounted in the aft section of each nacelle tied to the pump pressure line. They are used as low-pressure warning units in the hydraulic system by turning on a light in the co-pilot's panel.

Icing conditions are indicated by a switch that monitors pressure in the fuel filter. When the icing point is reached, the switch actuates a solenoid valve on North American's F-86 Sabre jet.

The function of the switch on the Lockheed F-94C is to warn the pilot by an indicating light on the panel that the pressure is gone in the fuel tank. This switch is used on fuselage fuel tanks.

Two switches are used on the P2V—one on each wing. They indicate to the pilot, via a light on the cockpit, when fuel is low in the tip tanks. On the T-33, a switch indicates to the pilot, by panel light, that all the fuel has been transferred or that transfer pump is inoperative. Another switch on this aircraft is used to tell the pilot, by panel light, that the booster pump is inoperative.

Pressure actuated switches are widely used on auxiliary power units. Solar uses a Meletron switch that incorporates a snap-action switch that controls ignition.

A switch mounted on the radar wall of the P2V-5 turns on the pump to recharge the accumulator in the emergency system when pressure is low. It also turns off the pump when accumulated pressure is sufficient. Another application is on the radar wall of the P2V-5. This switch is located between two shut-off selector valves. When the main hydraulic pressure drops below 7 lbs. per sq.in., a switch automatically opens a valve to the emergency hydraulic system. If the system is low, the switch actuates a gear-driven pump to build up the pressure.

MINNEAPOLIS-HONEYWELL REGULATOR COMPANY

Minneapolis, Minn.

Until 1940, the only electronics in the average airplane were in its radio. Then the Minneapolis-Honeywell Regulator Company built a C-1 autopilot for the Army Air Corps. Today, there's scarcely a plane that flies which doesn't use one or more electronic control systems.

They stabilize flight; measure and control fuel; control engines; provide "platforms" for bombsights, turrets, or radar; guide missiles; and provide many other functions.

Honeywell—the world's largest manufacturer of automatic controls for home and industry—built a record 35,000 C-1 autopilots for World War II bombers. It also turned out over 100,000 turbosupercharger regulators. With this as a start the company elected to remain in aeronautics.

Today, Honeywell's Aeronautical Division's six buildings and its flight-test hangar and facilities sprawl over half a million square feet, it has one of the most advanced engineering and test installations anywhere, and its field service engineers can be found wherever Honeywell equipment flies.

To the 5,000 employees of the Aeronautical Division falls the task of keeping pace in controls with the breakneck development of modern aviation. Take flight control, for example.

Honeywell C-1 autopilots in the famous B-17's, B-24's, B-25's, B-26's, and B-29's helped in the pinpoint bombing of Berlin and Tokyo. Soon after World War II ended, the E-6 autopilot was developed and flew on the B-36's and B-50's of our postwar strategic air force.

Yet, even before the E-6 was in production, the aeronautical Division's engineers were at work on the MH-11 for such jets as the F-89, the RB-66, Canada's CF-100, and others still classified. At the same time, Honeywell developed one of the first helicopter autopilots—the E-12. It was followed by later models that introduce entirely new control concepts—among them "cyclic-stick steering," which eliminates all cockpit autopilot instruments except an on-off switch.

Today, the engineers are busy on the MH-14 for supersonic jet planes that are, themselves, still on the drawing boards.

The Dynamic Damper is another electronic accomplishment of Honeywell engineers. Designed for top performance at a certain speed, today's sleek craft have less stability at other speeds. The Damper restores it through gyros and an electronic system that provides instant automatic correction in the yaw axis.

The importance of constant altitude control to accurate high-level bombing tossed another challenge to Honeywell's engineers. They met it with a barometric-pressure-detecting altitude control of extreme sensitivity that has become a part of newer autopilots. It provides altitude control down the bombing run, eases pilot fatigue in formation or straight and level flight, and helps save fuel, thus increasing the range and performance of bombers and fighters.

From its extensive flight control activities Honeywell has designed, developed, and mass-produced extremely sensitive but rugged air-borne gyros now used in many ways. It is, for example, the largest producer of the floated gyro.

Honeywell's turbosupercharger regulators took World War II aircraft into the higher altitudes. They also took the Aeronautical Division into a second major area of activity—engine controls for both jet- and propeller-driven planes. Utilizing unique test facilities and design techniques, work is now under way on controls that automatically regulate the desired amounts of fuel and air flowing to the engines of jet planes.

From engine controls the Aeronautical Division branched into precision fuel measurement. Until Honeywell developed the first three-wire bridge capacitance fuel measurement system, gasoline was measured by a float gage in the tank just as it is in an automobile. With the Honeywell system it is now accurately recorded in pounds. Such systems are now standard for the industry, and Honeywell systems are used on more than 40 types of military and commercial aircraft.

However, jet planes use fuels ranging from kerosene to high-octane gasoline. Because of various plane designs, these fuels must be carried in tanks of many sizes and shapes. A gage was needed which could accurately record any kind of fuel in any kind of tank. Aeronautical Division engineers not only provided it but even combined the readings from all the tanks into one gage that shows the busy pilot the amount of energy—and flight time—he has left.

Finally, Honeywell turns out dozens of component parts—activators, amplifiers, valves, switches, Mach sensors, accelerometers, and others used in the mechanical, electrical, and hydraulic systems that fill the modern mid-century "flying machine."

NATIONAL CREDIT OFFICE, INC.

New York, N.Y.

The total working capital resources of all manufacturers of airplanes in the early 1930's was little more than $30,000,000. Few of the companies had experienced sustained profitable operations. And for that reason, ownership of aircraft securities was not widespread. Acquisition of the capital required to finance the tenfold expansion in sales over ensuing 5 years was difficult. Accordingly, mercantile and bank credit was relied upon heavily as the principal source for additional operating funds.

To meet that clear need for a specialized credit service, National Credit Office, Inc., expanded its coverage to include the manufacturers of airplanes, engines, accessories, and equipment and the commercial air lines. Later, its service was extended to cover the manufacturers of the increasingly complex electronic equipment utilized in communication, navigation, and weapons systems. NCO sponsors Credit Discussion Groups, which provide credit executives throughout the industry the opportunity to exchange experiences and opinions. It has made, upon request, financial surveys used in the formulation of procurement policies and has assisted in the preparation and refinement of procurement regulations.

NCO's specialized services have been utilized by vendors in expediting the flow of raw materials by purchasers in locating sources of supply.

F-86D Sabre.

F-86H Sabre.

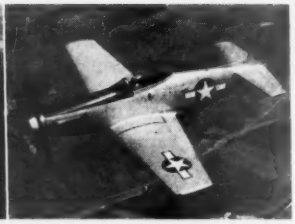
FJ-2 Fury.

F-86F Sabre.

AJ-2P Savage.

F-86A Sabre.

T-28A Trainer.



P-51H Mustang.

NORTH AMERICAN AVIATION, INC.

Los Angeles, Calif.

From the first BT-9 trainer, antecedent of a long series of highly successful training aircraft, down to the present supersonic F-100 jet fighter, North American Aviation products have been distinguished by their advanced design and mission suitability. As a result of this technical excellence, plus a remarkably effective production organization, the company has built more airplanes than any other company in the world.

Principal products during World War II were the P-51 Mustang fighter, described by a Congressional committee as "the most aerodynamically perfect fighter plane in existence"; the B-25 Mitchell bomber, used in every theater of the global war; and the T-6 Texan trainer, which was standard training equipment in the air forces of the United States and 34 allied nations.

North American's most famous product since the war has been the F-86 Sabre jet, the nation's first swept-wing production fighter. Only airplane capable of meeting the Russian MIG-15 on even terms, the F-86 has shown unquestioned superiority in combat, as evidenced by a 12 to 1 combat-kill ratio in Korea. Various models of the F-86 have held the official world speed record since 1948.

In addition to F-86 Sabre day fighters, the company is now producing for the Air Force the F-86D Sabre interceptor, the F-86H Sabre fighter-bomber, the T-28A trainer, and the new F-100A Super Sabre day fighter. For the Navy the company is producing the FJ-2 Fury carrier-based fighter, the AJ-2 carrier-based bomber, the AJ-2P photoreconnaissance airplane, and the T-28B trainer.

Since 1945 the company has also established itself as a leading contractor in the fields of guided missiles, rocket power plants, guidance and control equipment, and nuclear power-plant technology.

At present, North American operates principal manufacturing plants in Los Angeles and Downey, Calif., and in Columbus, Ohio. A smaller facility is located in Fresno, Calif. Total employment is approximately 52,000, including 4,800 in airplane engineering activities and a like number in missile and control-equipment engineering activities.

B-25J Mitchell.

SNJ-4 Texan.

B-45A Tornado.

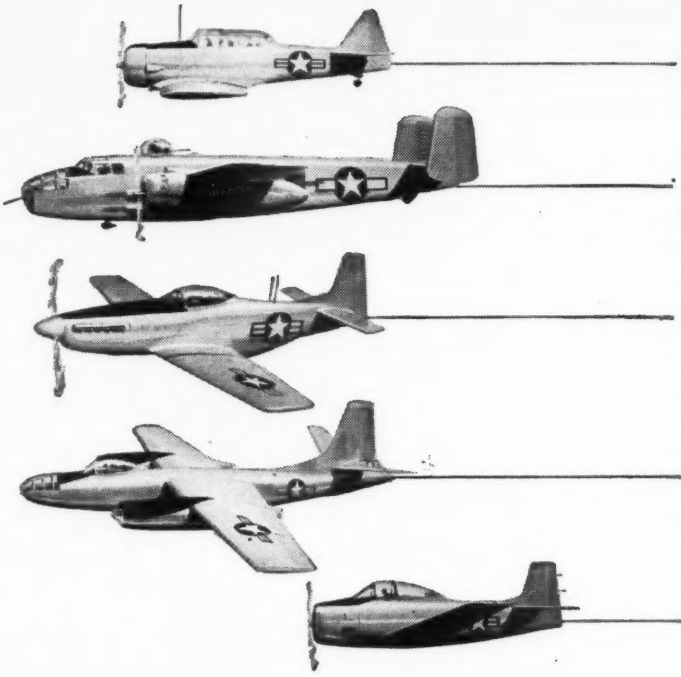
F-82E Twin Mustang.

BT-9C Trainer.

O-47A Observer.

Navion.

North American Aviation delivers its 50,001st airplane



T-6 Advanced Trainer—Used by 33 Allied Nations in W. W. II. Provided close tactical ground support in Korea.

B-25 Mitchell Bomber—Served in all theaters in W. W. II in several different bombing capacities... including famous first bombing of Japan. Rugged, practical, heavily armed.

P-51 Mustang—Leading fighter of W. W. II. Served as photographer, dive bomber, strafer, escort, spotter, for close ground support. Held line in Korea before *Sabres* arrived.

B-45 Tornado—First operational multi-jet airplane to fly in the U. S. First to fly non-stop across the Pacific.

T-28 Trainer—Faster than many W. W. II fighters with top speed of 346 MPH. 1,000 already delivered to Air Force. Now being delivered to Navy.

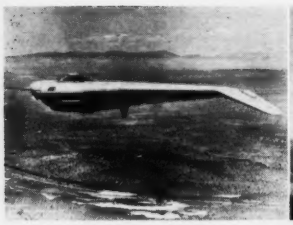
F-86 *Sabre* Jet—News making king of MiG Alley with kill ratio of 12 to 1 over MiGs. Produced in Australia and Canada and in Italy for NATO. Acclaimed as best all 'round fighter in the world.

F-86D *Sabre* Jet—America's only one-man, all-weather interceptor. Rocket firing. Now operational as primary continental defender... with 700 MPH *plus* speed.

FJ-3 Fury Jet—Latest of North American's FJ Series of Navy carrier-based fighters. With faster speed and rate of climb and superior firepower.

F-100 *Super Sabre*—Tri-sonic performance with overall weapon effectiveness. Now in production for Air Force. Flies faster than speed of sound in level flight.

NORTH AMERICAN HAS BUILT MORE AIRPLANES THAN ANY OTHER COMPANY IN THE WORLD



N1M Flying Wing.

N3 Patrol Bomber.

P-61 Black Widow.

F-89D Scorpion.

NORTHROP AIRCRAFT, INC.

Hawthorne, Calif.

From its very beginning, the story of aviation has been one of rapid unceasing evolution. A vision of the future, continuous research, and patient experimentation are needed to make this evolution possible. Northrop Aircraft, Inc., feels that, by emphasizing these basic engineering precepts it has helped make the evolution a little more rapid.

No single area of aeronautical development better exemplifies Northrop's tradition of achievement through research than that of flight controls. Back in 1939 when the N-1M, an all-wing airplane, was contemplated, it was apparent that conventional flight controls and surfaces could not be used because of the lack of an empennage. Something new was required. Consequently, longitudinal and lateral controls were combined in "elevons," trailing-edge control surfaces that function both as ailerons and elevators. Today this development is influencing the design of delta-wing airplanes and guided missiles.

Directional control of the flying wing could not be obtained by means of a conventional rudder. Again, something new was needed, and the best and simplest means found for providing directional control was a pair of split flaps at the wing tips that could be opened to produce drag at either tip for turning. Opening both flaps simultaneously produced effective deceleration. This split flap gradually evolved into the split aileron speed brake, one of the distinctive and valuable features of Northrop's F-89 Scorpion.

Aileron speed brakes give pilots increased control over flight speed in all attitudes. They make rapid deceleration possible—up to 0.5g—and give improved lateral control of the airplane. In vertical dives the airplane can be held to air speeds below the limit Mach Number, and in level flight it is possible to reduce speed from maximum velocity to stall in a matter of seconds. Air speed can be precisely controlled during final approach, and the landing roll can be greatly reduced.

Much credit for the success of the Scorpion speed brake must be given to Northrop's full power control system, for without it design of the speed brake from structural and mechanical points of view would have been unusually complicated. The full power control system on the F-89 is the first to be used on a production airplane. Flight control is effected through cable systems to hydraulic servo valves that direct and meter hydraulic fluid flow to control surface actuating cylinders.

The full power control system is made necessary by the high speeds of modern high-performance aircraft. As an aircraft enters the near-sonic speed region, air-load distribution across the airfoils changes, so that "feel" taken directly from control surfaces does not give the pilot correct indication for control of the aircraft. And at high speeds, forces are so extreme that a pilot would be unable to move the control surfaces without power controls of some kind. The full power control system, then, has a dual function. It provides stick-and-rudder "feel" properly associated with the flight path, and it puts more power in the pilot's hands for control of the airplane at high speeds. Full power controls will be increasingly necessary in the future as airplanes of greater and greater speeds are developed.

The history of elevons, speed brakes, and full power control systems illustrates the way in which technical development pays off in practical, highly effective products. Northrop has utilized its technical knowledge in the building of noteworthy aircraft, such as the N-3PB seaplane patrol bomber, the P-61 night fighter, and the F-89 all-weather interceptor.

The N-3PB was ordered by the Norwegian government early in World War II for operations against German warships in the narrow rock-bound fiords of Norway. In less than a year it was designed, produced, and delivered in quantity. For years it maintained its position as the world's fastest operational military seaplane.

When a night fighter was needed to guard against bombing attacks by the Germans and Japanese during World War II, the P-61 Black Widow was designed for that purpose and was produced by the hundreds at Northrop. One of the first production fighters to employ radar, it played a major role in stopping night-bombing forays by the enemy.

Northrop's F-89 Scorpion, currently in large-scale production for the Air Defense Command, is a third example of an airplane embodying technical development in a weapon designed for a given military job. The U.S. Air Force wanted an all-weather fighter-interceptor. It had to carry radar to seek out enemy bombers, to be fast enough to intercept them, and to have enough fire power to destroy them. All models of the Scorpion meet these requirements. The model now in production, the F-89D, stresses fire power. In its wing-tip pods it carries 104 2.75-in. rockets, which can be fired all at once or in groups.

These airplanes illustrate Northrop's function: design and production of airplanes to do a better job. Every year the jobs grow more difficult. National security requires airplanes and missiles of greater and greater capabilities; national economy requires conservation of resources and military funds. Northrop is organized to design air weapons to these requirements and produce them in quantity.

In following the course charted for itself, Northrop is looking forward to the next 50 years of powered flight, confident that the evolution of piloted and pilotless aircraft will continue, determined to make that evolution a little more rapid.

PAN AMERICAN WORLD AIRWAYS, INC.

New York, N.Y.

Now that international civil aviation has become an essential part of our foreign trade, our holiday travel, and our national defense, it is interesting to recall the early problems that once strained American engineering and operating skills.

Our problems were quite different from those of our foreign rivals. To tap the rich markets of the Far East, a European air line had a relatively easy overland route through the Middle East and India, where there were places to land every few hundred miles. The largest ocean in the world—8,000 miles of the Pacific—separated the United States from the same markets.

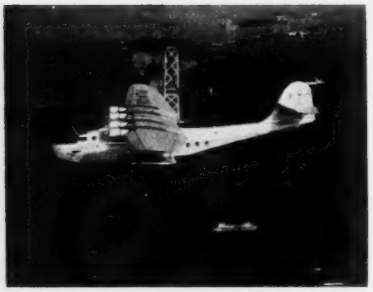
Arctic Sentinels

Thousands of miles away, long-range Northrop F-89 Scorpions stand guard night and day along the top-of-the-world route to America's heart, defending our homes and industry • These lethal USAF defenders will "scramble" at the first flash-warning from the polar radar chain. With deadly armament, latest radar, and ability to range over a defense zone up to 2000 miles in depth, they can strike, follow, harass, and destroy an invader hours before he can reach target • The Scorpion F-89 is America's most heavily armed fighter. It is a product of the precision team of Northrop men and machines.

NORTHROP

NORTHROP AIRCRAFT, INC. • HAWTHORNE, CALIFORNIA

Pioneer Builders of Night and All Weather Fighters



The Martin M-130 used by Pan American World Airways for its first Transoceanic passenger service across the Pacific.

Other air lines could be content with the relatively gradual development of small planes with limited range. Indeed at that time, it was thought that large planes would never be commercially sound. To reach its world markets, the United States had to resort to radical departures demanding hitherto unachieved efficiency in aircraft and operating techniques superior to anything previously needed.

The preparation began in the early thirties in an area today thronged with hundreds of thousands of air travelers—the Caribbean. In this "laboratory," experience was gained which made possible later scheduled service across the Pacific and Atlantic oceans. At the same time, tenders to manufacturers were issued as early as 1932 for the design and development of transoceanic four-engined flight equipment.

Development of these aircraft contributed not only to the progress of Pan American but also to the air-transport industry as a whole. The development of the Sikorsky S-42 effectively disproved the prevailing theory that the larger the plane, the less load it could carry in proportion to its own weight. This plane had a ratio of useful to gross load of 36 per cent, a remarkable achievement for that time. The later Martin M-130 had an even higher ratio of 41.5 per cent, and it was with this airplane that the first transoceanic passenger service across the Pacific was established.

Many factors contributed to the success of these airplanes. For their day, they had high aspect ratios. A wing loading of 30 lbs. per sq.ft., in the case of the S-42, was 50 per cent higher than planes then used in domestic service. High-lift wing flaps were newly developed but were essential to provide additional lift to get a heavily loaded craft off the water. New engine designs with low specific fuel consumption and controllable-pitch propellers used on these airplanes both were advanced developments.

With all these engineering achievements, operating techniques had to keep pace. In the Caribbean laboratory, the basic principles of scientific control of flight were developed first with the special training of flight crews in navigation, power-plant performance, and long-range communications. With the new science of air-mass analysis, it was possible to chart a three-dimensional weather map. This gave the pilot wind velocities and directions at various altitudes and enabled him to forecast flight times and fuel requirements. Long-range radio communications and direction-finding devices developed in the Caribbean were also essential to overocean navigation.

Pioneers of the Pacific will recall the "pressure pattern" flying between San Francisco and Honolulu. Pilots would head for "Jones's Corner," either north or south of the center of a pressure area to pick up the essential tail wind to help the airplane to its destination.

A "howgozit" chart was developed to check forecast flight operations with actual performance. It was from this chart that the famous phrase "point of no return" had its origin.

Technical developments have had their effect on world commerce. The airplane has opened new markets, has created new industries at home and abroad, and has made personal salesmanship possible on a worldwide basis. Today more than a million people each year fly abroad, more than twice as many Americans as ever went before Pearl Harbor. Indeed, more people go abroad by air than by sea.

Careful research is now in progress looking toward improvements of the aviation art. In 25 years we have increased the speed of travel from 100 to over 300 m.p.h. In a few years, we will add another 200 m.p.h. to the speed of overocean travel. Again, travel time over the principal trade routes of the world will be cut nearly in half.

JUAN T. TRIPPE, *President*

THE PARKER APPLIANCE COMPANY

Cleveland, Ohio

To serve effectively the aircraft industry, The Parker Appliance Company has established on the West Coast a separate subsidiary—Parker Aircraft Company—which conducts all of Parker's aircraft activity other than the manufacture of jet-engine accessories.

Parker has pioneered in the development of valves for aircraft fuel and vent systems—both those delivering fuel from ground to aircraft tanks and those directing and controlling the flow of fuel from tanks to engines. For the tank fueling phase, Parker supplies the aircraft industry with high-speed fueling nozzles and adapters capable of delivering better than 600 gal. per min. from ground to aircraft. Serving to harness properly this rapid rush of fuel to aircraft tanks is Parker's tank-mounted fuel level control valve, which is 40 per cent lighter than average line-mounted valves. The outstanding dependability of this valve is demonstrated by the fact that its diaphragm, which can withstand pressures up to 900 lbs. per sq. in. without fatigue or failure, has never ruptured in service.

A recent innovation of Parker Aircraft Company is its unique test stand, which enables air-frame manufacturers to evaluate the performance of aircraft fuel systems components under situations duplicating the actual high-flow conditions of modern high-speed aircraft. The stand is built to test transfers of fuel up to 1,200 gal. per min.

Parker's recent fueling developments include the design of a new-type reeling device for tanker aircraft engaged in mid-air refueling operations and also an improved probe and drogue design for the actual air-to-air fueling contact.

In addition to fueling systems, Parker Aircraft devotes a great deal of development and production activity to components for aircraft hydraulic systems. One of its most important contributions along this line is its series of shear plate directional control valves. The extreme adaptability of these valves helps simplify hydraulic systems used in actuating such items as landing gears and wing flaps. Parker's double-wall cylindrical accumulators have established new standards with respect to reliable low-leakage performance, which is vitally important for the job they do in aircraft hydraulic systems.

At the facilities of the parent company in Cleveland, Parker has a separate Engine Accessories Division supplying jet-engine manufacturers with some eight different engine accessories, most prominent of which are its fuel nozzles and deicing valves. Watched with keen interest by both engine and air-frame manufacturers is Parker's current development of a variable-area fuel nozzle, which promises superior jet fuel atomization throughout its entire range of operation—from extremely low flow to extremely high flow. This affords better starting in low-temperature regions, as well as superior performance and economy at slower operational speeds—a factor of tremendous importance not only for the military but also in commercial jet transport considerations.

Parker's earliest contribution to the aviation industry came with its development in the twenties of the original Parker tube fitting, which was subsequently to become the industry standard for aircraft purposes. Because this fitting made practicable the extensive use in aircraft of tubing for

EEMCO

technical bulletin

SPECIAL MOTOR FOR *shock* LOADS

This specialized EEMCO motor design employs an in line double spur gear reduction for heavier operating loads or applications where shock loads are experienced, such as air compressors. It is rated at 2½ h.p. for continuous duty, 27 volts D.C. Output speed is 3650 RPM. Unit includes radio noise filter and standard AND 20001 mounting pad and drive.

ELECTRICAL ENGINEERING & MFG. CORP.
4612 West Jefferson Blvd.
Los Angeles 16, California

3-519

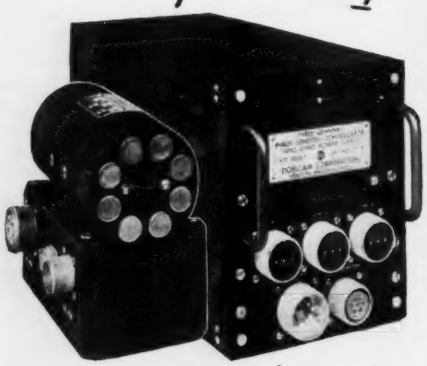
A link between sensors and recorders

Doelcam

VFDD

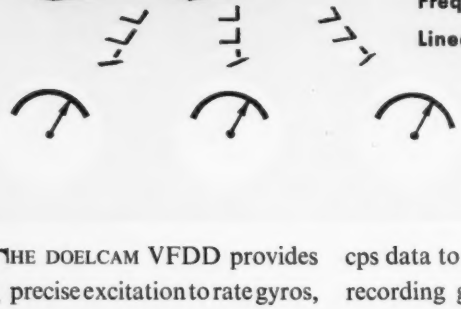
for

Flight Test Instrumentation



A precision 400 cps Power Supply and 3-channel Demodulator unit

Voltage regulation
Frequency stabilization
Linear demodulation



Write for Bulletin VF2

THE DOELCAM VFDD provides precise excitation to rate gyros, free gyros, position indicators or synchros for accurate measurement of flight parameters. In addition, the instrument includes 3 demodulator channels to transform 400 cps data to d-c signals for use with recording galvanometers.

Doelcam CORPORATION
SOLDIERS FIELD ROAD, BOSTON 35, MASS.
West Coast Office: 304 Tejon Pl., Palos Verdes, Calif.
Instruments for Measurement and Control
Gyroscopic Instrumentation • Servomechanisms
Synchros • Microsyns • Servo Motors

K GYROS for fire control computing, flight test instrumentation and control applications.

MICROSYN position indicators measure angular displacement for application in process control and data transmission.

SYNCHROS in 4 standard series transmit and receive electrical information with unsurpassed precision.

hydraulic systems, aeronautical engineers were able to proceed vigorously with drawing-board plans for such major modifications and improvements as retractable landing gears, brakes, and a variety of larger more extensive control surfaces.

PESCO PRODUCTS DIVISION, BORG-WARNER CORPORATION

Bedford, Ohio

Pesco Products Division, Borg-Warner Corporation, was founded in 1933 as the Pump Engineering Service Corporation—dedicated to better products and better service for the aircraft industry.

The company's first products were gear-type hydraulic pumps and vane-type fuel pumps, which, because of their efficiency and dependability, were readily accepted by the industry and soon became the standard of comparison.

By 1939, the line had been expanded to include vacuum pumps, anti-icing pumps, propellor feathering pumps, hydraulic motors, hydraulic valves, and vacuum regulating valves. It was at this time that Pesco became a member of the Borg-Warner family of industries.

Under the management of R. J. Minshall, President, the company prospered and grew so that, during World War II, Pesco produced 80 per cent of the fuel pumps for American aircraft.

During the War, Pesco announced "Pressure Loading," an entirely new concept of hydraulic pump design, providing volumetric and torque efficiencies in excess of 90 per cent by eliminating most of the internal leakage found in conventional gear pumps. This is accomplished by using hydraulic pressure from the discharge of the pump to maintain a minimum end clearance between the gear and bearing faces. This clearance is maintained throughout the service life of the pump regardless of load, viscosity, or temperature conditions, thereby maintaining new pump efficiency at all times. "Pressure Loading" has made possible today's line of hydraulic pumps developing 3,000 lbs. per sq.in. pressure.

In 1941, also, Pesco supplied the fuel pump for the first American-built jet engine. Since that time Pesco has kept pace with jet-engine development, having developed a fuel pump model for every American-built jet engine now flying.

Early in the War, the "Pressure Loading" principle was successfully applied to gear-type fuel pumps, opening the way to supplying the ever increasing pressures demanded by the jet engine designers.

In 1947, Pesco announced the development of a "dual pump," a tandem-type high-pressure fuel pump for turbojet and aircraft gas-turbine engines, containing both main and emergency pumps combined with automatic changeover valves all enclosed in one housing. This represented a significant advance in safety, for, should the main pump fail, the emergency pump would automatically supply enough fuel to operate the engine at full power. This is in contrast to the early types of jet-propelled aircraft which carried electric-driven standby pumps capable of operating the engines at only partial power output. The "dual pump" also eliminated the weight penalty for the electric motor of previous installations.

Pesco has continued to pioneer in the development of tandem-type high-pressure fuel pumps and is today supplying pumps with four elements—three gear type and one centrifugal, in one housing. Operating pressures are now in excess of 1,000 lbs. per sq.in., and output is as high as 200 gal. of jet-engine fuel per min.—all without external lubrication of any kind.

In 1945, Pesco developed a series of d.c. electric motors to meet aircraft requirements for power of 1/100 to 6 hp. A companion series of high-frequency a.c. induction motors ranging in size from 1/100 to 9 hp. was announced in 1953. Both series of motors are built in six coordinated frame sizes, combining the advantages of custom design with standardized parts.

1949 marked the opening of Pesco's new factory in Bedford, Ohio. This modern, one-floor plant houses a complete metallurgical laboratory for the testing of all materials prior to use, an electrical laboratory and a research laboratory for the testing of hydraulic equipment, as well as complete manufacturing facilities. A separate laboratory building for the testing of the company's high-pressure fuel pumps also contains an altitude chamber for testing the operation of aviation equipment at temperatures as low as 70 deg. below zero and at pressures equivalent to an altitude of 80,000 ft.

PHILLIPS PETROLEUM COMPANY

Bartlesville, Okla.

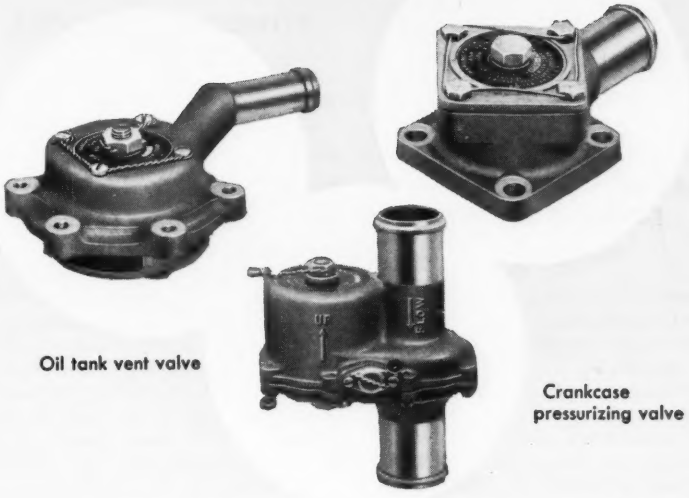
Phillips Petroleum Company, throughout its 36 years, has been a pioneer in aviation as well as in petroleum. The Company, with a fleet of nine airplanes, has an outstanding record among oil companies for the continuous industrial use of aviation, including flight testing. Eary aviation pioneers received important encouragement from the company.

Standard-Thomson

Barometric

VENT VALVES

Oil tank vent valve



Oil tank vent valve

Crankcase pressurizing valve

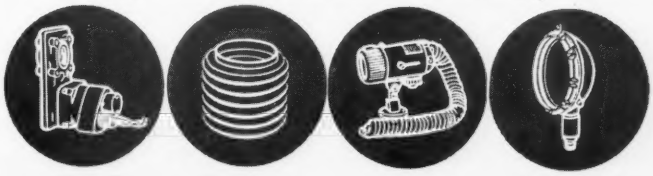
for accurate pressure control in oil tank or crankcase

These small, lightweight, precision assemblies produced by Standard-Thomson can be adapted to meet the specific requirements of any type of service . . . Pressure ranges, air-flow capacities, aneroid element closing and vacuum relief can all be varied; and fittings and connections can be built to meet individual needs. For complete information on the various types of approved vent valves produced by Standard-Thomson, please write:

STANDARD-THOMSON CORPORATION • DAYTON 2, OHIO

Standard-Thomson

Makers of USAF-approved bellows • valves • lights



Shut-off Valves | Tech-Forge Flexible Couplings | Cockpit Lamp Assembly | Vaporproof Cabin Lamp

Phillips' research programs have always had a strong aviation emphasis, participating actively in the early crucial standardization for aviation fuels and lubricants. More importantly, Phillips' research, manufacturing, and sales efforts have pioneered in nearly all the major ingredients of aviation gasolines, isopentane, alkylates (including diisopropyl), hydrocodimers, cumene, and superfractionated base stocks. Landmarks were 1938 when the company went into the manufacture of military 100-octane number gasoline in a big way with some of these ingredients and, when early in the War, the first HF alkylation plant was put into operation. Phillips has the highest yield of aviation gasoline from crude oil and operates the refinery with the highest yield of jet fuel from crude oil.

Phillips is now busily engaged in research on jet fuels, rockets, and specialty synthetic rubbers and other plastics, as well as on many of the immediate problems of aviation, commercial and military.

PIASECKI HELICOPTER CORPORATION

Morton, Pa.

Piasecki Helicopter Corporation is in its Tenth Anniversary Year. From the beginning, the company has devoted its entire engineering skill to the development of the tandem rotor transport-type helicopter.

The world's first successful tandem rotor transport design, the XHRP-X, was flown by Piasecki in 1945. This was a prototype for the famous HRP-1 "Flying Banana," which proved its greater load-carrying abilities in demonstrations of mass air-sea rescues, of Marine assault tactics, and as the first antisubmarine warfare helicopter. The HRP-1, a ten-place transport, was prototype for the even more powerful H-21 Work Horse, now in production. The H-21 is capable of carrying 22 troops, more than double the load of its prototype.

(Top) XHRP-X helicopter. *(Bottom)* USAF H-21 Work Horse.

In a specially designed Navy fleet utility helicopter, the HUP, Piasecki used the tandem rotor design in a small five- to seven-place helicopter capable of being landed aboard cruisers, as well as aircraft carriers.

The world's largest helicopter, capable of carrying 40 passengers is, again, the tandem rotor design. This transport, the YH-16, is scheduled to fly late in 1953.

POWER GENERATORS, LTD.

Trenton, N.J.

Power Generators, Ltd., is primarily engaged in the development of aircraft accessories and handling equipment—i.e., aircraft carrier catapults, arresting engines, barriers, barrier triggering devices, arresting engine hydraulic controllers, constant-speed alternator drives, etc. PGL is also doing development work in the field of expeditionary catapults for land use—armament accessories, guided missiles, pilot ejection seats, etc. Finally, PGL is continuing its pioneer work in the field of high-powered aircraft steam power plants, the main components of which are now being tested by the Armed Services. Complete plans for a 50,000-hp. twin-engined installation are being worked on for flight at Mach 1.5.

Apart from the foregoing activities, PGL is extensively engaged in the design of engine test stands, compressor research test rigs, turbine and combustion test rigs, special high-altitude test equipment for ram-jets, supersonic wind tunnels, etc.

PGL maintains its principal facility at Trenton, N.J. The work of PGL is not entirely confined to aircraft development—i.e., its main endeavor is in the field of naval propulsion equipment and ordnance development. However, in connection with these allied activities, aircraft design techniques are being applied.

A. J. LARRECQ, *President*

THE PURE OIL COMPANY

Chicago, Ill.

The Pure Oil Company, now in its 40th year, has long been a leader in supplying aviation fuels and lubricants. The Company began with a single well

Smiths Bluff Refinery of The Pure Oil Company, Nederland, Tex.

in the Cabin Creek, W.Va., oil field in December, 1914, and, through the Company's own exploration and geological work, has discovered production in twelve states.

Pure Oil's network of refineries operates in Texas, Ohio, West Virginia, and Michigan. Every form of transportation including ocean-going tankers, inland waterway vessels, crude and product pipelines, and automotive and overland equipment is used by the Company.

Retail marketing operations are carried on through Pure Oil outlets and service stations in 24 states, and industrial products are sold nationally.

RADIOPLANE COMPANY

Van Nuys, Calif.

Radioplane Company, the nation's largest manufacturer of aerial targets, is located at the west end of the San Fernando Valley Airport, 8000 Woodley Ave., Van Nuys, Calif. In addition to producing target drones in quantity for the Armed Forces, it is also engaged in research and development in the target and guided-missile fields.

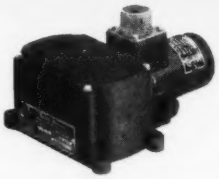
Radioplane Company has been actively engaged in the design of radio-controlled pilotless aircraft for many years. In 1935, three 8-ft. span radio-controlled models were built for the Army and were successfully flown at Muroc Dry Lake, Calif., under radio control at a speed of approximately 60 m.p.h. As a pioneer in this industry, the founders of Radioplane Company not only designed the vehicle, but, of necessity, had to design the radio receiver, radio transmitter, the launching mechanism, and the various ground-handling equipment.

In the interim between 1935 and the commencement of World War II, extensive engineering and experimentation resulted in Radioplane Company's being in a strategic position to offer the Armed Forces a dependable radio-controlled aerial target, which was produced in large quantity and used extensively by all the services.

MORE THAN 50,000 IN USE

BENDIX-PACIFIC GENEVA-LOC ELECTRIC ACTUATORS

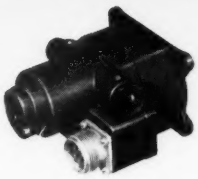
Available for all Air Valves, Fuel Valves, Hydraulic Valves, Engine Controls, High-Low Blower Controls



SERIES 108
GENEVA-LOC ACTUATORS

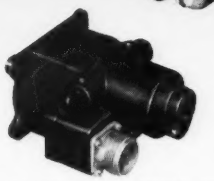
Simplicity is the keynote of these actuators. A mechanical cam does the positioning while the motor does the work. There are no clutch-brakes or adjustable limit switches.

More than 20 standard and noise-free models for 45°, 60°, 72° and 90° positioning are readily available at low cost



SERIES 118
GENEVA-LOC ACTUATORS

Fast acting, trouble free actuator for most hydraulic, air and fuel valves. Provides ample torque in a minimum of operating time. Incorporates the exclusive Geneva movement. No clutch-brakes or adjustable limit switches. Minimum actuating time .5 sec. (Time to 3 sec. available.) 2-position 90° only.



SERIES 118 HIGH TEMPERATURE
GENEVA-LOC ACTUATORS

Identical to standard Geneva-Loc Actuators but designed for operation at temperatures up to 250°F. These are proven, conservatively rated actuators suitable for operating in the proximity of 500-600°F temperatures. High temperature versions of the 108 series actuator also available.

SERIES 128 MINIATURE
ROTARY ACTUATORS

This unusually compact, light weight actuator develops 100 pound-inches torque at a speed of 15 RPM. This is made possible through the development of an entirely new concentric square series motor (not permanent magnet type). The design is readily adaptable to other torque and speed ratings.

Write for complete information

GENEVA-LOC SAFETY LINK

Eliminates all adjustments from the linkage, providing an adjustment-free system which reduces installation time to a minimum and assures virtually trouble-free service.

Bendix

Pacific Division
Bendix Aviation Corporation
NORTH HOLLYWOOD, CALIF.

East Coast Office: 475 Fifth Ave., N.Y. 17 • Export Division: Bendix International, 205 E. 42nd St., N.Y. 17 • Canadian Distrib.: Aviation Electric, Ltd., Montreal

AIRCRAFT HYDRAULIC CONTROLS · AIRBORNE RADAR · SONAR · INDUSTRIAL HYDRAULIC CONTROLS · TELEMETERING · ELECTRO-MECHANICAL EQUIPMENT

Following cessation of World War II, Radioplane Company was faced with the alternative of staying in the radio-controlled target business or attempting to enter a new field of commercial activity and production. This company chose the former, and it is believed that the decision was a wise one. As a result, Radioplane Company has accumulated a wealth of knowledge in this specialized field and is considered by many people in the Government services to be the most capable, reliable, and low-cost target producer in this country.

Today, Radioplane Company has approximately 600 employees, and its facilities exceed 115,000 sq. ft. of manufacturing space. More than 100 engineers are currently engaged in research and development. The company is presently operating at a greatly reduced capacity and has available personnel and facilities to handle new design, development, and production.

Radioplane Company's principal production item is a target powered by a 72-hp. two-cycle engine. The target is radio-controlled, easily maneuverable, and capable of high speeds. When antiaircraft fire scores a hit or the target is to be voluntarily landed, a parachute is deployed to permit safe descent of the plane for reuse. Radioplane Company's other activities include the development and manufacture of launching equipment, starters, handling stands, etc. The company's work in electronics covers research on, and production of, controls and autopilot systems. Additional development contracts with the services are in the field of air-frame recovery and parachute design. Currently under test are types of jet-propelled targets designed for high-speed operation.

In July, 1952, Northrop Aircraft, Inc., concluded arrangements to acquire 100 per cent of the stock of Radioplane Company. Whitley C. Collins, who is one of the founders of Radioplane Company and who has guided the company through its uniformly successful history, is President of the company and is also a member of the Board of Directors of Northrop Aircraft, Inc. William Larrabee is Vice-President—General Manager of Radioplane Company; Ferris M. Smith is Vice-President—Engineering; and M. W. Tuttle is Vice-President—Military Relations. Radioplane Company's manufacturing and research program is an ideal adjunct to Northrop's rapidly expanding operation.

J. B. REA COMPANY, INC.

Los Angeles, Calif.

The J. B. Rea Company, Inc., a research, development, and manufacturing organization in the field of automatic controls, is primarily concerned with the application of servomechanism principles to component integration in automatic systems for airplanes, helicopters, guided missiles, torpedoes, submarines, data handling, industrial processes, etc.

One of its major programs is the development of an air-borne central control computer to incorporate digital and analog circuitry in the most efficient combination. Such a central air-borne computer would carry on the functions of automatic flight control, automatic navigation, guidance, and automatic pilot control without the redundancy of present-day aircraft equipment.

Also under development is a 400-channel strain-gage digital recorder, which will sequentially digitize 400 analog voltage signals and store them on a magnetic drum in less than 2 sec.

In the field of helicopter control, the J. B. Rea Company is presently developing an automatic hovering control system, making an analysis of an aeroelastic helicopter to determine the requirements for a new autopilot, studying a simple roll-and-pitch damper system, and analyzing a speed-and-pitch control for the rotor. Other programs include the preparation of a text entitled "Automatic Control of Aircraft" and the development of an automatic cruise control computer for long-range aircraft.

Although one of the youngest firms in the field of automatic controls, the J. B. Rea Company's $2\frac{1}{2}$ years of work is becoming of increasing importance in the field of aeronautical engineering.

REPUBLIC AVIATION CORPORATION

Farmingdale, L.I., N.Y.

Republic Aviation Corporation is recognized for a number of developments in aeronautical engineering and manufacturing and for its production of more than 15,000 P-47 Thunderbolts and 4,457 Thunderjets at a critical time in history.

These two records of mass production of first-line aircraft won for Republic the title of the world's largest producer of warplanes.

Accomplishment of such production in the time available was not easy. There were many technological problems, and the feat also required a rapid increase in trained and unskilled personnel.

In the latest and still current emergency, Republic led the way again with its record of T-Jet production. A major problem was finding trained aeronautical engineers, available only on a limited scale.

To solve this problem, Republic set up a unique recruitment and training program to give 6 weeks of transition training in aviation engineering to nonaeronautical engineers. The 6-week course was so successful that a 6-month curriculum was introduced. Today, between 85 and 90 per cent of the company's engineering personnel are men and women who originally had been trained in nonaeronautical fields.

In the less highly skilled fields, Republic undertook other training programs as employment jumped from 7,747 in 1950 to 22,000 in 2 years.

Production of the new F-84F Thunderstreak, the Air Force's first swept-wing fighter-bomber, now is under way on a large scale, and employment figures again are jumping.

There were other problems in the production field.

One answer to better planes at less cost in less time was in Republic's heavy-forging program. Republic's interest was aroused after World War II, when company officials studied reports of Germany's progress in the field.

The company then became one of the first air-frame manufacturers to respond to an Air Force request in 1948 that the industry incorporate large forgings in development of new aircraft.

The 200 forgings designed into Republic's F-84F Thunderstreak range from a 12-ft. two-sectional wing spar (one of the largest production aircraft forgings ever made) to smaller frame members and diagnonal ribs.

Use of forged front and rear spars in the wing, instead of the conventional built-up parts, saves 75 lbs. in each airplane. The forged front spar is made of three component parts and eleven fasteners, while a conventional spar requires 17 component parts and 468 fasteners.

Another major Republic contribution is its leadership in fixture alignment through optics. Taking the basic Taylor-Hobson optical instruments that had been used in England's shipbuilding and to a limited extent in its aircraft production, representatives of the Air Force visited air-frame builders in 1946 to get their reactions to optical tooling.

Republic showed immediate interest and went ahead with its own preliminary planning to determine what could be done to adapt the basic instruments for efficient fixture alignment. The company developed the principle and instruments by which optics can be applied practically to everyday aircraft tooling through use of a Telescope-Aligning Bracket and a Spherical Mount for the telescope. Republic invented or improved more than 15 devices for use in optical tooling.

Showing the mobility of optically built tools, the company, in 1951, disassembled two fixtures constructed

A Salute

TO THE LOW-FLYING MEN!

All hail to the ace in the "wild blue yonder" . . . but let's give with some man-sized cheers for the lads who slug it out at hill-top level. From the time they take off . . . till the mission is completed, these strategic fighter bombers and tactical close support pilots face a brutal blasting all along the way.

➢ ➢ ➢ Sniped at by small arms and machine guns . . . bracketed by flak with the constant hazard of limping home harassed by enemy aircraft . . . these are the stout warriors for whom we've planned Republic's rugged THUNDER-craft . . . to get them there . . . do the job, and bring them back.

REPUBLIC AVIATION

FARMINGDALE, LONG ISLAND, N. Y.

Makers of the Mighty Thunderbolt · Thunderjet · Thunderstreak

under an Air Force contract in its Farmingdale, N.Y., plant, flew them to the West Coast, and reassembled them as a feature of a 4-day demonstration of optical tooling for some 120 military and industry leaders.

Out of Republic's research laboratories have come many other contributions, such as the mid-air fighter refueling technique proved in the first jet fighter Atlantic and Pacific crossings by F-84 Thunderjets. To aid in this work, the company developed a fuel-system test laboratory, which simulates flight conditions on the ground and enables engineers to check pressures and temperatures at 25 key locations. These laboratory principles have been used by others in the industry for research into fuel problems.

A few of the other recent developments pioneered by Republic include work with automatic explosion- and fire-suppression systems; interchangeable wing-tip and pylon tanks for extra fuel; exploration of multicell honeycomb construction; research into forming techniques for titanium and the use of magnesium, titanium, and new aluminum alloys for many aircraft parts customarily made of steel; development and increased use of plastics parts for economy and weightsaving (the Thunderstreak uses more than 150 laminate plastic parts and perhaps 1,500 other types of plastic parts); and infrared defogging of aircraft windows.

A. V. ROE CANADA LIMITED

Malton, Ontario, Canada

Canada's biggest employer and pivot of Canada's thriving aviation industry was given its initial vital impetus by the Canadian government's decision to build up a self-sufficient industry as quickly as possible to avert any possible serious supplies emergencies should global warfare break out again. The company, A. V. Roe Canada Limited, now occupies approximately 3,000,000 sq.ft. and employs over 14,000 workers. Some 1,000 suppliers of A. V. Roe Canada scattered across Canada add their thousands indirectly to the number of Canadians now actively engaged in Canada's aviation industry.

The design of a specific Canadian jet fighter and power plant was ordered from the fledgling A. V. Roe Canada at its organization 8 years ago. Because of its unique geography, Canada needs a supersonic, long-range, day-and-night fighter, capable of carrying extraordinary armament. Success crowned the company's efforts from the start. Today, the aircraft, the CF-100 Mk. 3 is in squadron service with the RCAF, with the Mk. 4 version going into production immediately. The engine, the turbojet Orenda, is not only serving the CF-100 but is also powering the F-86 Sabre being turned out in Canada for RCAF operations overseas.

One of the first Sabres to be equipped with an Avro Canada Orenda, changing over from an American jet engine, broke five world speed records within 3 weeks.

JOHN A. ROEBLING'S SONS CORPORATION

Trenton, N.J.

Ever since America took to the air, John A. Roebling's Sons Corporation, pioneers in the development of wire products, has been supplying the needs of the aircraft industry.

When John A. Roebling conceived and fabricated a wire rope in 1841, it brought to the American industrial scene a new and important engineering tool. Soon after the success of his wire rope became evident, John Roebling adapted its use to the suspension bridge principle, making possible a number of the most spectacular engineering projects in the world. These included the Niagara Gorge Bridge, the first successful railway suspension bridge ever built, and the most widely known of all the bridges he designed, the famous Brooklyn Bridge.

It was natural, therefore, for the pioneering Wright brothers to use a Roebling product on their famous "flying machine." When Orville Wright took off in man's first successful powered flight, the "Kitty Hawk" was trussed by Roebling wire.

It was natural, also, for the infant aircraft industry to turn to the pioneers in the development of wire and cable to supply its needs, and, as a consequence, the first NACA report carried data supplied by Roebling.

As a matter of further interest, Charles A. Lindbergh's famous ship, "The Spirit of St. Louis," was braced by Roebling wire, and the ferrules for the wings, wire cord for all controls, and the insulated wire that kept the engine running and the dashlights illuminated were all made by Roebling.

The Roebling Corporation has continued to keep pace with the astonishing progress and growth of the aircraft industry. It supplies a wide range of wire products for both airplane production and operation; aircord and air controls, arresting gear for aircraft carriers, wire rope for cranes, conveyers, and endless other types of equipment, slings and mooring pendants.

Roebling is proud of its close relationship with the history and growth of the aircraft industry—an industry that in a few short decades has converted the world into a neighborhood.

ROHR AIRCRAFT CORPORATION

Chula Vista, Calif.

Rohr Aircraft Corporation, which was founded in 1940 by Fred H. Rohr, is a manufacturing and service organization engaged in building power packages and many other components for both military and commercial planes. Largest customers at this time include Boeing, Convair, Douglas, and Lockheed.

The Company began operations in a rented warehouse building and its first product was cowling for Lockheed. Late in 1941, Rohr obtained a contract to build power packages for the B-24 and the Company's success with this type of manufacture led it to specialize in the field. By the end of the war it had built 38,000 power units for various types of planes. In addition, it also had expanded to the conversion field and had transformed a number of PB2Y's into cargo carriers for more extended service.

At the end of World War II, the Company occupied 650,000 sq.ft. of manufacturing and office space. For several months after the end of the war, with the cancellation of so many military contracts, employment dropped from the peak of 9,800 to about 800. Then, with orders for commercial plane power packages coming in, employment and plant activity picked up until, by the time the Korean War came along, about 3,000 were at work and the Company's backlog was $14,000,000.

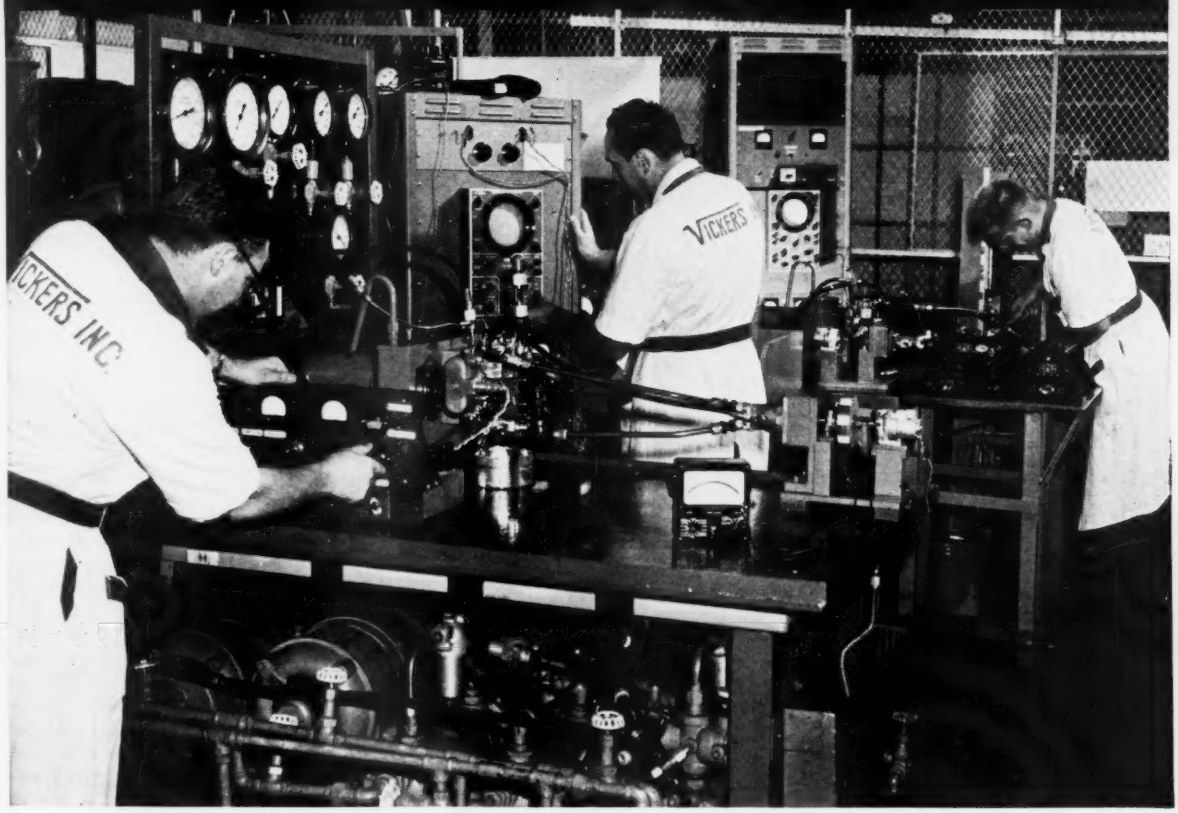
Since 1950, the Company has been in a continuous program of expansion. Its employment now is approximately 9,000; its plant facilities occupy 1,250,000 sq.ft., and it has a backlog of more than $182,000,000, which includes both military and commercial work.

First major step in the expansion program was taken in May, 1952, when a tract of 80 acres was purchased at Riverside, Calif., and construction was started on a new plant. In less than a year this plant, which now comprises about 350,000 sq.ft. and employs 2,200, was completed and in full production, its chief output being KC-97 power packages for the Boeing Stratotanker.

The Rohr plant at Chula Vista now is manufacturing nine different types of power packages, employing reciprocating, turbocompound, turboprop, and jet engines. Among the major airplanes for which these power packages are being built are the Convair 340 Liner, the Douglas DC-7, the Lockheed Super Constellation, and the Boeing B-52 all-jet bomber. In addition, the Company also manufactures aft sections, wing-tip tanks, exhaust systems, augmentors, and scores of individual parts that total more than 25,000.

ONE OF A SERIES

You Get Many Benefits
by Specifying VICKERS® Hydraulics



Research | that means improved oil hydraulic equipment

The list of pioneering developments in hydraulics contributed by Vickers research is long and impressive. Among the most important are:

Hydrostatic Relief Valve • Commercial Power Steering • Balanced Vane Type Pump • Flow Control Compensator • Axial Piston Pump and Motor

These are fundamental developments that have been of vital importance in the progress of hydraulics. They are representative of a large line of equipment that, with Vickers experienced application, assures you the best in any type of hydraulic operation. Vickers, with unmatched laboratory and basic research facilities, continues to lead the way in the oil hydraulics industry.

VICKERS Incorporated
DIVISION OF THE SPERRY CORPORATION
1414 OAKMAN BLVD. • DETROIT 32, MICH.

Application engineering and service offices: El Segundo, California, 2160 E. Imperial Highway
Houston 5, Texas, 5717 Kirby Drive • Detroit 32, Michigan, 1414 Oakman Blvd.
Additional service facilities at: Miami Springs, Florida, 641 De Soto Drive

ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921

GENISCO'S MODEL B G-ACCELERATOR

EASIER TO OPERATE!

EASIER TO MAINTAIN!

Rugged, low cost unit provides fast, accurate calibration of accelerometers and other equipment under operational acceleration forces.

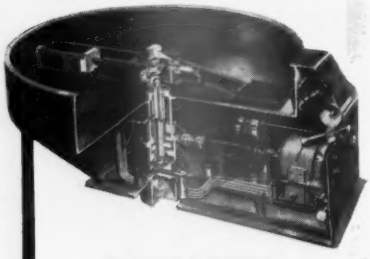
The mounting platform of the Genisco Model B, G-Accelerator accommodates instruments up to eight cubic inches in volume and 25 pounds in weight. Boom rotation is variable between 5 and 420 RPM, and is controlled by a single handwheel on the control panel. Maximum drift is less than 0.1% per minute, and maximum wow above 10 RPM less than 0.5%. The range of G-loadings is from .017 to 120 G's at the maximum radius of gyration of 24 inches.

Three separate instruments assure accurate RPM measurement!

A built-in, line frequency strobe disc system accurately measures boom speed at 82 harmonics over the full RPM range. In-between speeds can be determined by a counter-and-timer which counts boom revolutions, in any adjustable time interval, to the nearest 1/10 of a revolution. A standard aircraft sensitive tachometer, accurate within 1%, is also provided for rough speed indication.

Electrical leads have extremely low noise levels!

Eight solid silver slip rings are normally provided. These are designed for instrumentation rather than for power leads. Each is individually shielded and has a precious metal brush, resulting in noise levels so low oscilloscopes may be used at highly sensitive settings. Standard current carrying capacity of each slip ring circuit is 0.5 amperes continuous duty, with maximum resistance ½ ohm. Combinations of power and instrumentation rings can be supplied.



OPTIONAL EQUIPMENT AVAILABLE

1. **OPTICAL SYSTEM**... for observing instruments while subjected to G-loadings.
2. **AIR SYSTEM**... four ¼", leak-proof pressure or vacuum ports for gas or liquids.
3. **OVERHEAD SLIP RING ASSEMBLY**... provides additional power or instrumentation slip rings.
4. **ACCESS DOORWAY**... for ease in mounting test instruments.
5. **COVER ASSEMBLY**... conserves power by minimizing air pumping action, keeps dust out.
6. **DEEP GUARD RAIL**... 16" deep, provides more clearance above mounting table.

For detailed specifications on the Genisco Model B, G-Accelerator write to the Director of Sales, Genisco, Inc., 2233 Federal Avenue, Los Angeles 64, California.

Genisco
INCORPORATED

For the last 2 years the Company has conducted an extensive research program on the use of titanium. Many problems were encountered in handling the new "wonder metal." These had to do chiefly with welding and forming. As a result of research, considerable new equipment has been installed, and for several months parts have been made of titanium in increasingly larger numbers. The DC-7, for example, uses titanium for more than 90 per cent of its nacelles. As the program moves ahead and one after another of the problems involved in handling the metal are solved, the use of titanium takes on an increasingly important role in the fabrication of parts that demand high strength, a minimum weight, and high heat-resistance qualities.

Sales of products for the fiscal year ended July 31, 1953, amounted to more than $62,000,000, with a net profit of $2.56 per share on the 600,000 shares of common stock. This compared with a $1.91 per share profit for the preceding year.

Executive personnel of the Company has remained virtually unchanged since its founding. It now consists of Fred H. Rohr, President and General Manager; J. E. Rheim, Executive Vice-President; A. F. Kitchin, Vice-President—Administration; B. F. Raynes, Vice-President—Manufacturing; F. E. McCreery, Vice-President—Engineering; Charles E. Barnes, Vice-President and Manager, Riverside plant; S. W. Shepard, Secretary; and Guy M. Harrington, Treasurer. The four vice-presidents were appointed on August 1, 1953, being promoted from executive positions. None has been with the Company less than 10 years.

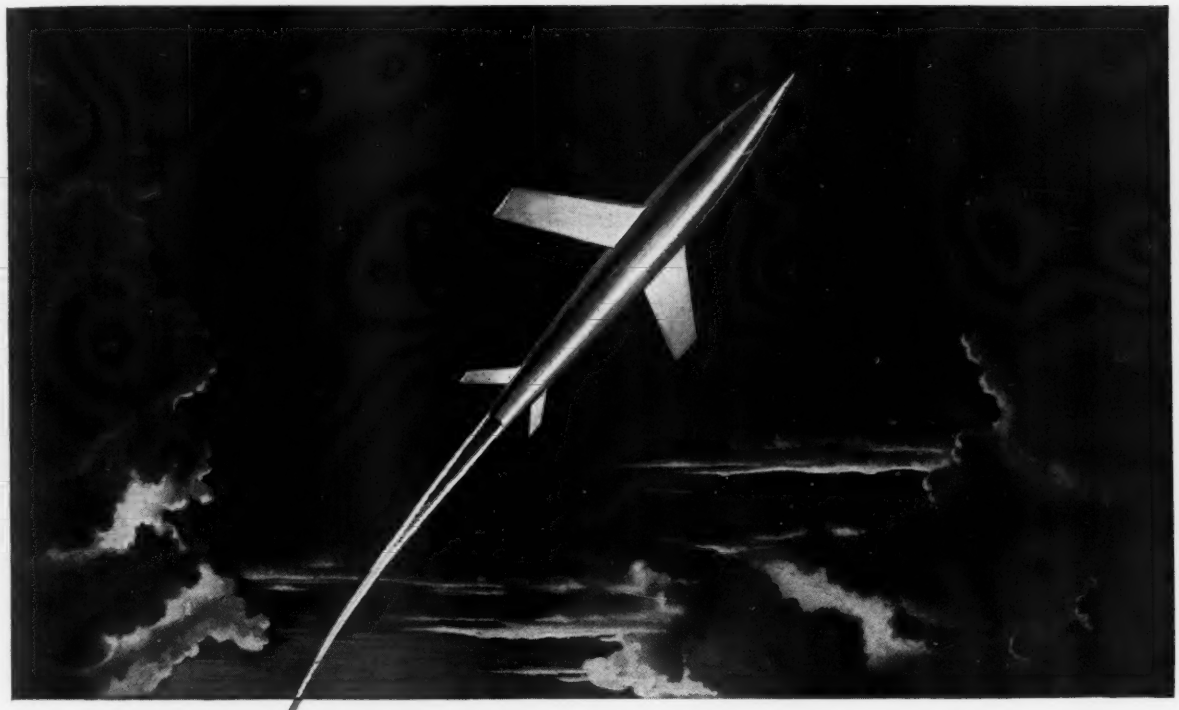
PAUL ROSENBERG ASSOCIATES

Mount Vernon, N.Y.

The science of physics is basic to aeronautical engineering. Modern aviation developments result from fundamental research and development in physics. Nevertheless, there is usually a gap between the discovery of a basic new fact or phenomenon in science on the one hand, and the application of this new knowledge to practical purposes on the other.

Paul Rosenberg Associates, a firm of consulting physicists, bridges and shortens this gap by rendering professional services of consultation, research, and development in the practical application of physics and related sciences. PRA thus plays a unique role in modern aviation development.

The firm's spheres of activity include: radar and other electronic navigational aids; ultrasonic trainers for air-borne radar and for air-borne loran; and



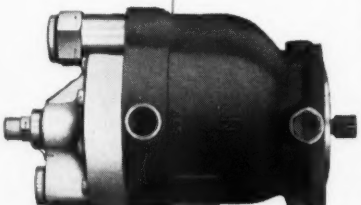
OUTWARD BOUND · · · Controlled All the Way by—

STRATOPOWER
HYDRAULIC PUMPS

To the layman, the pinpointing of a destination for a guided missile is still pure magic. But to the engineer, the control and guidance of rockets and guided missiles in flight simply means another application for STRATOPOWER quality and advanced design.

The unerring performance of STRATOPOWER Pumps has been demonstrated times without number down through the years. At sea level and at heights still to be achieved these perfect examples of precision engineering provide the fluid power that positively answers the question of weight vs. horsepower as well as the equally important requirement of long-lived dependability.

In the designing of any high pressure hydraulic circuit there are definite advantages in STRATOPOWER Pumps. Whether yours is a problem for constant or variable delivery, high or low temperature operation, capacities from .25 to 30 gpm, STRATOPOWER will provide the pump to 3000 psi that will resolve that problem NOW!



The 66W Series of STRATOPOWER Hydraulic Pumps embrace a range of models from 2 to 10 gpm at 1500 rpm with continuous pressures to 3000 psi. Designed for maximum continuous speed of 3750 rpm . . . intermittent speeds to 4500 rpm.

Write ***Get the full story on STRATOPOWER constant and variable delivery Pumps for your hydraulic circuits.***

WATERTOWN DIVISION
THE NEW YORK AIR BRAKE COMPANY
STARBUCK AVENUE • WATERTOWN • N. Y.

WATERTOWN DIVISION
THE NEW YORK AIR BRAKE COMPANY
760 Starbuck Avenue • Watertown, N. Y.

Kindly send me information on STRATOPOWER Hydraulic Pumps

☐ Constant delivery ☐ Variable delivery

Name_____

Company_____

Address_____

City_____ Zone___ State_____

DEPARTMENT OF TECHNOLOGY
BUFFALO PUBLIC LIBRARY

aerial photography, photogrammetry, and cartography. The laboratory of PRA is well equipped for research and development work in a variety of fields of experimental physics including optics, precision mechanics, and ultrasonics.

Paul Rosenberg Associates is also active in the fields of operations analysis and information theory. These two modern extensions of physics and applied mathematics are powerful tools for the practical solution of many difficult problems in engineering and industry.

SCHRILLO AERO TOOL ENGINEERING COMPANY

Los Angeles, Calif.

Schrillo Aero Tool Engineering Company was established early in 1938 for the specific purpose of designing and producing precision cutting tools peculiar to the usage of air-frame manufacturers. Many specialized items that were developed during this period have now become the standards of today's requirements.

Soon after the original purpose was fulfilled, the firm branched into the manufacture of precision gages to assist in the production and inspection of aircraft components and assemblies. Many problems relative to fits, interferences, and proper mechanical assembly were solved and brought down to their practical and economical manufacture.

Today the gage branch of the activity is carried out under modern laboratory conditions. Temperature and humidity are rigidly controlled as a safeguard in maintaining the advanced position of the company in this particular pursuit.

Later, as the requirements of the aircraft industry expanded, the manufacture of precision aircraft components was undertaken. Today a completely equipped plant produces aircraft actuator assemblies, hydraulic components, servomechanisms, pumps, and relative equipment.

A separate division manufactures high-capacity cabin supercharger assemblies. For the past 3 years, the firm has contributed to the advancement of the air-conditioning and cabin-pressurization systems of the Douglas DC-6 and DC-7 airplanes.

To keep pace with the ever changing and ever increasing demands of the aircraft industry, a specialized research and development department has recently been organized.

SEABOARD & WESTERN AIRLINES, INC.

New York, N.Y.

Seaboard & Western Airlines, Inc., pioneer transatlantic all-freight air carrier, was founded in 1946. In the intervening years its aircraft have flown over the historic trade routes of the North Atlantic between the eastern seaboard of the United States, Western Europe, and the Middle East from a base in New York.

Pioneering in the "lift" of bulk commodities across the Atlantic, Seaboard & Western Airlines, Inc., largest U.S. all-freight air line in the transatlantic trade, specializes in the movement of items such as this 14,200-lb. rudder stock flown from New York International Airport to Rome for a damaged oil tanker.

In addition to Seaboard's commercial services, another division, based at Los Angeles International Airport, executes Seaboard's contractual obligations to the U.S. Air Force in its Pacific airlift operations between California and Tokyo. Seaboard presently has on order four Super Constellation air freighters slated for delivery some time in 1954.

SHELL OIL COMPANY

New York, N.Y.

The newest in the list of contributions by Shell to aviation development is TCP, the gasoline additive that cuts sparkplug fouling and thus ensures more efficient combustion. This achievement stems from Shell's intensive aviation research program, carried out in laboratories at Martinez, Calif., and Wood River, Ill. The company's engine-testing laboratory at Wood River, for years in the forefront of work on engine development, is a pioneer in the field of jet fuels.

Early Shell research led to the production of iso-octane and, later, to the first commercial delivery of 100-octane fuel, which contributed so crucially to Allied victory in World War II.

The company's research program has been successful in improving not only gasoline but other factors in aviation as well. AeroShell Grease 7, introduced in 1951, combines for the first time extreme temperature range with high load-carrying capacities in lubrication of aircraft gear and actuator screws.

Recently, Shell developed VPI, a corrosion inhibitor dramatically effective in protecting engine parts in shipment and storage. Another new Shell contribution is Epon, an adhesive that opens new vistas in aeronautical engineering by replacing rivets in many structural applications.

SIMMONDS AEROCESSORIES, INC.

Tarrytown, N.Y.

Simmonds Aerocessories, Inc., since its organization in 1938, has won a reputation for its success in introducing to the U.S. aircraft industry advanced technical developments, many of which have originated in England and other European countries. Specializing in the development and manufacture of precision, electronic, hydraulic, and mechanical aircraft equipment, Simmonds has primarily concentrated on fuel-gage systems, direct fuel injection systems, explosion- and fire-suppression systems, and mechanical equipment such as cowling latches and push-pull controls.

Typical of Simmonds' contribution to the industry has been its pioneering work in the introduction of electronic (capacitance) fuel gaging for aircraft. Prior to World War II, all aircraft fuel gages were of the float-arm type. In 1946, Simmonds, drawing upon development work done by an associate English company, pioneered the first electronic fuel gage in a U.S. commercial transport plane—the Douglas DC-4 and the C-54 conversions for air-line use. From that initial installation, Simmonds has gone on to make installations on more than 40 types of modern aircraft, including the DC-6's and the Super Constellations, as well as the newer military models. Today, most all multiengined aircraft are equipped with the type of gaging system which Simmonds pioneered.

Another example of work done by Simmonds in the "off-shore procurement of technical ingenuity," is the work that the firm has carried forward for several years in introducing to America explosion- and fire-suppression systems. These systems are based upon experiments conducted by the Royal Aircraft Establishment, which demonstrated that explosions of fuel-air mixture begin with a rate of pressure rise which is initially relatively slow. Equipment utilizing these principles is designed to detect this initial pressure rise in a matter of milliseconds and to cause the discharge of suppressant fluids that, in effect, snuff out the explosion when it is still in a harmless stage.

Missile with a "one track mind"

...Bomber Defense

Defensive guided missiles launched from supersonic aircraft will depend upon electronic marvels that come as close to simulating human intelligence as any mechanism ever devised. Important functions of these "weapons of the future" are typical of those entrusted to systems made by Arma Corporation.

Complex electronic and electro-mechanical controls from Arma are an integral part of many of America's most advanced weapons. In basic research, design, development and manufacture, Arma Corporation has worked in close cooperation with the Armed Forces since 1918—and more recently, the Atomic Energy Commission. *Arma Corporation, Brooklyn, N. Y.; Mineola, N. Y. Subsidiary of American Bosch Corporation.*

ARMA ADVANCED ELECTRONICS FOR CONTROL

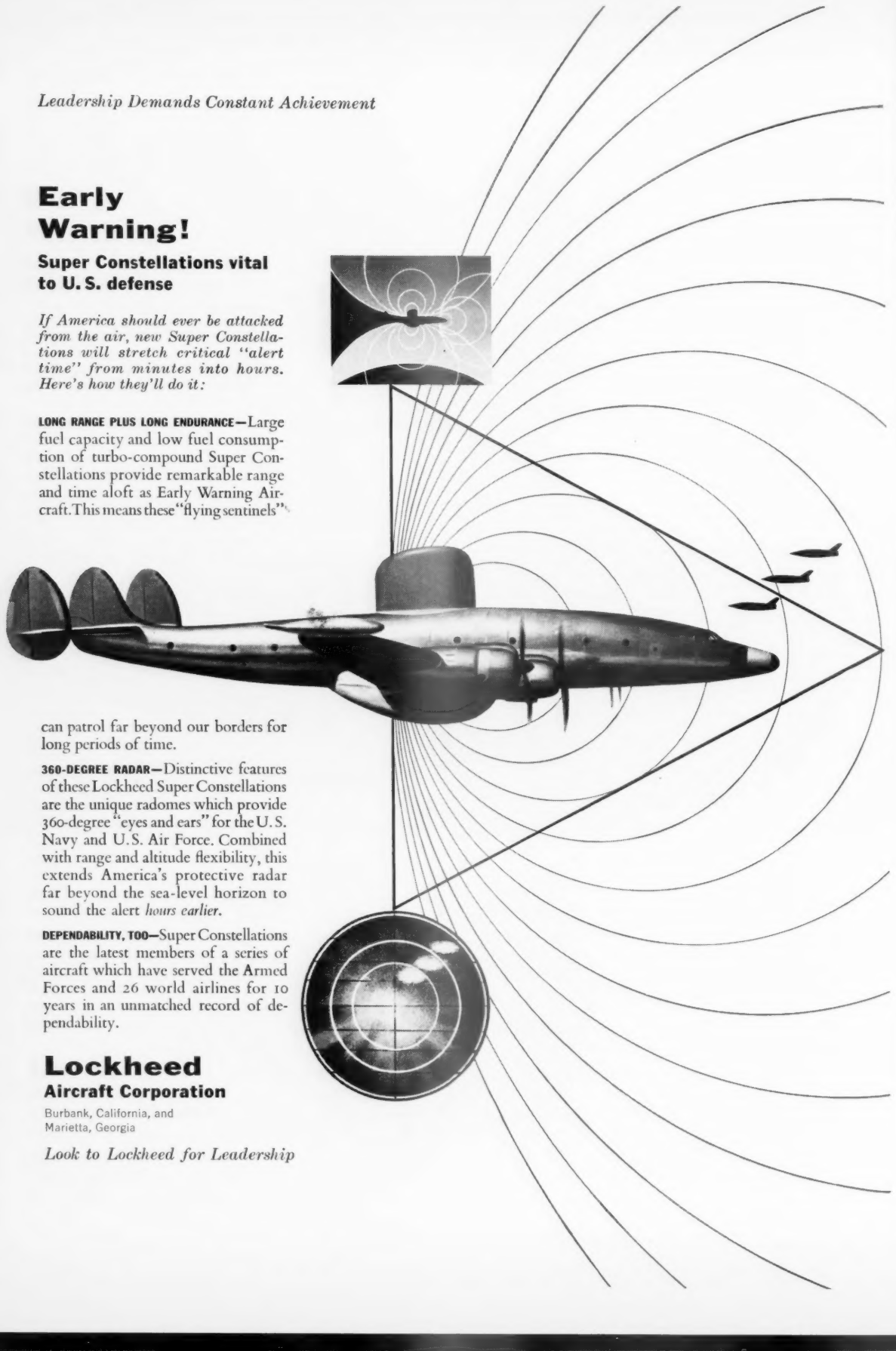
Leadership Demands Constant Achievement

Early Warning!

Super Constellations vital to U. S. defense

If America should ever be attacked from the air, new Super Constellations will stretch critical "alert time" from minutes into hours. Here's how they'll do it:

LONG RANGE PLUS LONG ENDURANCE—Large fuel capacity and low fuel consumption of turbo-compound Super Constellations provide remarkable range and time aloft as Early Warning Aircraft. This means these "flying sentinels"



can patrol far beyond our borders for long periods of time.

360-DEGREE RADAR—Distinctive features of these Lockheed Super Constellations are the unique radomes which provide 360-degree "eyes and ears" for the U. S. Navy and U. S. Air Force. Combined with range and altitude flexibility, this extends America's protective radar far beyond the sea-level horizon to sound the alert *hours earlier.*

DEPENDABILITY, TOO—Super Constellations are the latest members of a series of aircraft which have served the Armed Forces and 26 world airlines for 10 years in an unmatched record of dependability.

Lockheed
Aircraft Corporation
Burbank, California, and
Marietta, Georgia

Look to Lockheed for Leadership

Lockheed

Continental Defenders Comprise Unique Team

Of all U. S. aircraft manufacturers, the Lockheed Aircraft Corporation today produces the most complete team of airplanes capable of nearly every function of air defense.

With increasing emphasis on continental defense needs, Lockheed is building a record volume of specialized defenders of many types. And production of all Lockheed models is on schedule.

Important members of this Lockheed defense team are these three airplanes:

1. EARLY WARNING—Lockheed Super Constellations, with distinctive radar humps, are "flying radar stations" capable of hovering long hours at high altitude far beyond U. S. borders to warn against attack. (Called WV-2 by Navy, RC-121-D by Air Force.)

2. FLYING SENTRY—For long-range, long-endurance patrols at lower levels, the Navy uses P2V Neptune Bombers, especially designed to protect U. S. coastlines from sneak attack by submarine. Secondary missions: rocket attack, mine laying, torpedo attack, photo reconnaissance.

3. ALL-WEATHER JET INTERCEPTOR—While both the Early Warning Aircraft and the P2V Neptunes are on constant patrol, Lockheed F-94 Starfires are based at strategic continental points, ready to intercept any attacker in daylight or darkness, regardless of weather.

Peace today is as firm as the strength behind it, and other Lockheed models in production contribute toward this peace. These include the T-33 Jet Trainer (Navy, TV-2) in which 9 out of 10 of our jet pilots earn their wings, and the C-130 military transport, only transport designed from the ground up for turboprop power.

PLANS FOR TOMORROW'S PLANES—Several new Lockheed models will be tested early next year. One of these will be the XF-104 Day Superiority Fighter. Others are too secret to be talked about. And designs 10 to 15 years from now are now taking shape in research by a special corps of engineer-scientists at Lockheed.

Working with several leading aircraft manufacturers, Simmonds has advanced the techniques of both explosion- and fire-suppression systems and is now manufacturing this equipment on a production basis for installation on several of the latest models of U.S. fighter aircraft.

A third and most recent example of the international liaison service performed by Simmonds is the work done in introducing to the U.S. the English system of "SARAH"—Search And Rescue And Homing equipment. This miniaturized radio-beacon equipment is designed primarily for use in locating lost personnel. The system provides each crew member with individual beacon equipment approximately the size of two small match boxes, weighing less than 3 lbs. and capable of transmitting a signal for approximately 60 miles for a period up to 19 hours. The SARAH beacon equipment can also send and receive voice for a lesser distance. Already officically adopted for use by the RAF, it is expected to have application in the U.S. for both military and civilian organizations.

With its administrative and engineering headquarters in Tarrytown, N.Y., Simmonds has recently put into operation a new factory at Vergennes, Vt.; other manufacturing plants are located at Danbury, Conn., and Glendale, Calif. In addition, branch offices are located at Dallas, Tex., and Dayton, Ohio.

SOCONY-VACUUM OIL COMPANY, INC.

New York, N.Y.

The progressive development of aeronautical science and the aircraft industry has been of major interest to Socony-Vacuum for many years and particularly during the past 20 years when aviation has come into its own. The principal contributions made by Socony-Vacuum have included the development of new fuels and lubricants and test methods for determining how to obtain the highest performance from these products.

Specifically, the great volume of aviation gasoline produced by the petroleum industry during World War II was made possible by the pioneering efforts of Socony-Vacuum on the catalytic cracking process for producing high rich mixture blending stocks. Socony-Vacuum not only lead in this process development but also installed the first commercial unit at its refinery in Paulsboro, N.J. In addition, the "Magic Bead Catalyst," the most modern version of this process, was developed by the company and was manufactured for the entire petroleum industry.

Aetco

ENGINEERING DIAGNOSIS

AETCO's comprehensive testing service gets to the root of any problem relating to the performance of aircraft components. AETCO will save your organization weeks of investigation, will free engineering personnel for other vital assignments.

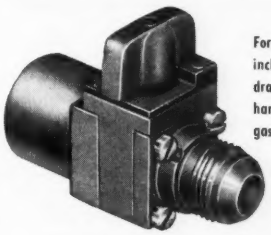
General aircraft component testing, including hydraulic, pneumatic, electrical (400 cycle AC-DC) and mechanical.

In-flight testing, too!

Aetco
1806-12 FLEET ST.
BALTIMORE 31, MD.

AIRCRAFT EQUIPMENT TESTING COMPANY

Before you specify
Check KOEHLER
BALL DRAIN VALVES



For 1/4, 3/8 and 1/2 inch OD tube in drain systems handling fuels, gases, oils, water-alcohol and corrosive fluids.

Koehler Ball Drain Valves are small, light, yet simply constructed and rugged. They meet USAF Specification No. 28208 and drawing No. 49F9798 performance and installation requirements. May be used at pressures up to 100 PSI; with Teflon seals, up to 500 PSI. Also available in large sizes for 5/8, 3/4 and 1 inch OD tubes. Write for catalogue or send specifications.

KOEHLER
Aircraft Products Co., Inc.
814 Vermont Ave., Dayton 4, Ohio
Representatives: Western Aircraft Supply Co.; C & H Supply Co.; Pranko Progress & Eng. Corp., Ltd.

Aviation gasoline development was also furthered by Socony-Vacuum's experimental engine work, which, in cooperation with the military services and commercial interests, led to the development of the test methods now used to evaluate high-performance aviation gasolines. In the course of this work the company laboratories produced prototype fuels of extremely high power potential for use by the aircraft-engine builder in developing their "super" engines.

Even before the close of World War II, this same type of work was initiated on jet fuels and has continued without a break for nearly 10 years. In addition to the extensive efforts aimed at ensuring an adequate supply of jet fuel in the event of any emergency, Socony-Vacuum efforts are directed at improving those fuel characteristics that will increase the reliability and durability of aircraft performance. Currently, this work is carried on in secrecy, and the results are being discussed only with authorized military personnel and representatives of the aircraft industry.

Complementing the extensive efforts on fuels, Socony-Vacuum's record in the field of lubricants and special oils is also a proud one. In the early days of aircraft engine development, the research conducted on lubricants showed the way through selected refining techniques using stocks from carefully segregated crude oils to produce oils that would meet the conflicting engine requirements of freedom from harmful deposits and elimination of exhaust valve guide corrosion.

The extent of Socony-Vacuum's participation in the field of special oils is illustrated by the fact that the company not only supplied practically all of the military requirements for aircraft hydraulic fluids during the War but, for several years, was the only supplier capable of meeting the extremely high standards set by the Army and Navy for these materials.

In addition to developing and supplying aircraft greases having exceptional properties for operation over extremely wide temperature ranges, Socony-Vacuum has also pioneered in the development of lubricants for gas-turbine-powered propeller-driven aircraft. The unique blend of materials synthesized in the research laboratory proved so successful in operation that it provided the basis for the present military specification.

SOLAR AIRCRAFT COMPANY

San Diego, Calif.

For a quarter century Solar Aircraft Company has concentrated on the design and fabrication of stainless-steel and other high-alloy components for high-temperature aircraft uses. As a pioneer in this particular field, Solar has made many significant contributions to the aircraft industry. Some of the highlights follow:

Exhaust Manifolds.—Solar began designing and producing manifolds for reciprocating engines in 1930 and has since produced over 425,000—more than any other firm. In making manifolds, Solar introduced the drophammer to the aircraft industry; developed the Sol-A-Die process, a unique and cheap method of making successive stage dies; and perfected a number of special welding techniques to speed manifold output. Among the exhaust systems produced by Solar were those for the Lockheed P-38, the Boeing B-29, and the Convair B-36.

Jet-Engine Parts.—For the last 10 years, a large part of Solar's production has been "hot parts" for jet engines. In this field, also, the company introduced many novel manufacturing techniques, such as automatic fusion welding machines and special machine tools. Recently, Solar has taken the lead in introducing mass-production techniques in the making of jet-engine components—conveyerized assembly lines, high-production special-purpose machinery, and volume welding methods—for large quantity output.

Afterburners.—Solar designed and produced the first successful jet-engine afterburner, test-flown at Patuxent on the Chance-Vought XF6U Pirate in November, 1947. This accomplishment followed earlier research on secondary combustion and on smoke generators. Today, every known afterburner uses features patented by Solar. Major design contributions by Solar have included afterburner control systems, burner assemblies, variable nozzles, and other components. The company has assisted almost every turbojet manufacturer in designing or producing afterburners.

Gas Turbines.—Since World War II, Solar has concentrated considerable research and development work in the small gas-turbine-engine field. One model now being produced, the Mars, is a 50-hp. unit used to power auxiliary generator sets for aircraft. These airborne power units have been ordered by the Air Force and by Douglas for use on the C-124 Globemaster. Another basic gas turbine developed by Solar, the Jupiter, of approximately 500 hp., has potentialities as a helicopter power plant.

Ceramic Coatings.—A major research and development accomplishment of Solar in recent years has been the perfection of a series of high-temperature ceramic coatings, known as the "Solaramic Process." These coatings extend the service life of stainless steel and other high alloys by protecting them against high-temperature oxidation and corrosion. Solaramic coatings have found many uses in aviation—on jet- and reciprocating-engine parts, on afterburner components, and on other aircraft items. Solar recently established the first mass-production coating facility for aircraft parts and is volume-coating transition liners and combustion chamber inner liners for General Electric J47 jet engines.

Stainless Alloy Castings.—Solar established a stainless alloy foundry mainly to supply the company's own needs for castings. In recent years, however, the company has accepted orders from aircraft firms for castings and has pioneered in developing alloy castings for various aircraft uses. The most recent innovation was the introduction on the West Coast of the shell molding process, for turning out high-quality castings at low cost. Because shell molding avoids many technological limitations of other alloy steel casting techniques, it promises to allow the use of castings in many aircraft applications where they were impractical previously. Currently, Solar is devoting much casting research to this end.

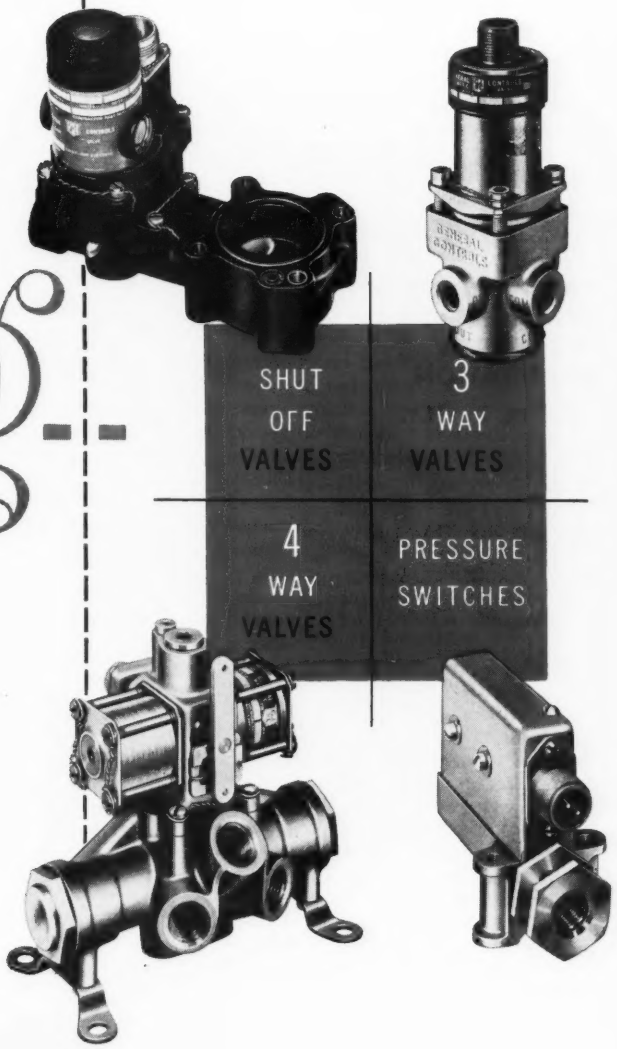
Aircraft Bellows.—Solar developed special machinery to form the corrugations of aircraft bellows hydraulically. This machinery is adapted for the volume production needed of lightweight, gastight flexible joints for jet engines, and the company is able to hydroform them in diameters from $^1/_2$ to 10 in. and in any length. Other Solar developments, such as automatic buttwelders, are also used in bellows fabrication.

Ducting.—From Solar's earlier experience in working with alloy steels, the company was able to contribute many design and production techniques in the growing field of ducting systems for jet aircraft. These pneumatic systems, which include air-bleed manifolds, lightweight stainless-steel tubing, bellows, and various other components, are becoming an increasingly important field to Solar.

Microjet.—Solar's most recent contribution to aviation is the Microjet, a unique control that directly senses jet-engine pressures and which replaces complicated electronic equipment. Embodying a completely new control principle, several hundred Microjets have been ordered by Westinghouse and are being produced for use on the J46 jet engine. In use, the Microjet computes under all flight conditions exactly what the turbine discharge pressure should be and, at the same time, notes any discrepancy between actual engine pressure and correct pressure. If an error exists, the Microjet automatically sends electrical signals to other controls that correct the pressure conditions. It is so

hi-g-

for aircraft



General Controls
hi-g®
controls

In engineering terms "high g" means high gravitation forces. In performance terms "Hi-g" means General Controls' reliable line of automatic pressure, temperature, level and flow controls for heavy duty under acceleration factors from 10 to 300G. The Hi-g line comprises electromagnetic pilot and shutoff valves... manual and motor-driven gate valves... electrohydraulic selector valves... gauge and differential type limit controls... all light in weight, compact in design and trustworthy in operation... handling a great variety of liquids and gases in a wide temperature range.
For high efficiency performance under extreme vibration and acceleration conditions it's General Controls Hi-g Controls... the best in automatic control for any machine that rolls, floats or flies.

GENERAL CONTROLS
Glendale, California • Skokie, Illinois
Manufacturers of Automatic Pressure, Temperature, Level and Flow Controls for Heating, Home Appliances, Refrigeration, Industrial and Aircraft Applications.
FACTORY BRANCHES IN 35 PRINCIPAL CITIES
See your classified telephone directory.

fast that pressure variations are recognized in a hundredth of a second.

Special Tools.—As Solar has concentrated on fabrication of alloy steels over the years, the company has developed many special tools for particular operations. Some of these tools attracted attention in the aircraft industry, and the company has built and sold limited quantities of automatic buttwelders, seam levelers, nibbling shears, expanders, and other tools to aircraft firms, both in the United States and abroad.

SPERRY GYROSCOPE COMPANY, DIVISION OF THE SPERRY CORPORATION

Great Neck, L.I., N.Y.

When Elmer A. Sperry founded the Sperry Gyroscope Company in 1910, he had in mind three possible uses for the gyroscope. The first was the gyroscopic compass for marine use, the second was the big gyro stabilizer for keeping ships from rolling at sea, and the third was the automatic stabilizer for airplanes.

Of the three applications, the third one appeared most fantastic and least practical. In 1910 there was no aircraft industry, and airplane instruments had not even been thought of. But looking back from this present year—the 50th Anniversary of Powered Flight—we see that it was the airplane stabilizer that opened the door to the widest horizon of the three—instruments for air transportation.

As early as 1912, Mr. Sperry designed, and his son Lawrence flew, the first successful gyro stabilizer in a Curtiss airplane at Hammondsport. In 1914, Lawrence competed with 80 entrants for an award offered by the French for a "stable airplane." Sperry won by a dramatic automatic flight over the Seine in a Curtiss Flying Boat.

When World War I broke out in that same year, the military fliers started to fly their primitive airplanes without instruments, and they had no need of automatic stabilizers. But as war experience rapidly expanded the role of aircraft, it was soon found that instruments were essential. The Sperry Company, through its experience with the stabilizer, realized the growing need for instruments in flight and was the first company in this country to produce a "complete line" of aircraft instruments. In those war years, however, a tachometer, an altimeter, an airspeed indicator, a ball bank, and a magnetic compass made up the "complete line."

By the end of the War, Sperry had added two more instruments to the list, the gyro turn indicator and the rate-of-climb indicator. These two instruments, though too late to be used in the War, proved to be most valuable in the early air-mail days in aiding the pilots who were struggling to master blind flight. They are now considered basic instruments.

During the years that the airways of the country were being installed to facilitate air transportation and the carrying of air mail, the Sperry Company turned to making ground equipment. Airway beacons and airport floodlights were developed so that flying could be a 24-hour activity.

By 1929, with over 12,000 miles of lighted airways and successful air-mail routes, blind flying was still not considered safe and reliable enough to carry passengers. The pilot needed more information and new instruments. A concerted effort was made to solve the problems under the sponsorship of the Daniel Guggenheim Fund for Aviation. Lieutenant James H. Doolittle was put in charge of the project. The Sperry Company, working closely with Doolittle, produced two new instruments for his airplane, a gyro horizon and a directional gyro. With these and several other improved instruments, Doolittle demonstrated that instrument flying was quite practical. The Sperry Company put these two instruments into production in 1930, and they were rapidly adopted throughout the world.

At about this time, large multi-engined airplanes were being introduced on the air lines so that passengers, as well as air mail, could be carried. In the military field, multiengined bombers were achieving long flights. Both of these developments called for a renewal of the endeavor to make flight automatic by adding an automatic pilot to relieve the human pilot.

The Sperry Company in 1933 brought out a new design of automatic pilot, taking advantage of all that they had learned in the intervening years. The first equipment was installed on Wiley Post's "Winnie Mae," and with it he set a new record by flying around the world solo in 7 days and 18 hours. This hydraulic type of automatic pilot soon came into general use both in commercial and military airplanes.

When World War II came, the demand for aircraft instruments increased many fold. The high performance of the military airplanes also demanded improved instruments. To meet this situation, Sperry brought out the first electronic automatic pilot, electric flight instruments, and the Gyrosyn compass. In addition to these improved instruments, new ones were added in the form of air-borne radar in the microwave field.

During the years since the end of World War II, the problem of instrument landing has received the greatest emphasis. In 1946, the Zero Reader Flight Director was demonstrated as an aid to instrument landing. The Zero Reader was the first of a new type of aircraft instrument, for it gave the pilot directions as to how to move the controls rather than a variety of information from which the pilot had to interpret his actions.

A system of automatic approach control has also been developed as an adjunct to the automatic pilot. Currently, a great deal of work is being done in a scientific study of weather and visibility as it affects the problem of landing.

The engine analyzer has been perfected during these years and is being used extensively on long-range flights to monitor in flight each cylinder's performance.

In such a constantly advancing field as aviation, a development program can never be permitted to lag, and so in aircraft instruments Sperry is at present actively developing new equipment demanded by the higher performance of jet airplanes and new systems of control to meet the problems of increased traffic.

During the 50 years leading to this supersonic age, thousands of developments have been labeled "Mission completed." But Sperry's job is always a "Mission extended," looking ahead, providing now for future needs.

STANDARD OIL COMPANY OF CALIFORNIA

San Francisco, Calif.

Standard Oil Company of California has assumed an outstanding role throughout the years both in pioneering in aviation and in keeping pace with its rapid growth. Not generally remembered is the fact that its aviation gasoline was purchased and shipped to the East Coast and used by such early fliers as Charles Lindbergh, Comdr. Richard E. Byrd, and others on their epochal transatlantic flights and by Maitland and Hegenberger, Smith and Bronte, and numerous Dole racers in the first transpacific hops to Hawaii.

In the late twenties and early thirties, before air-line transportation was generally available, Standard of California operated the largest fleet of privately owned airplanes of any commercial enterprise in the country. For several years, commencing in 1928, Standard erected and maintained six 10,000,000-c.p. aviation beacons at strategic points in the West, augmenting the 2,000,000-c.p. airways beacons provided by the CAA.

Perhaps the most important single contribution to aviation by any commercial enterprise was the painting of town name signs by Standard on the

The Most Trusted Name in Ignition

safeguards every component part of your ignition system

From Lindbergh's history-making flight to today's record breaking jets, Bendix ignition equipment has played a spectacular part in aviation progress.

While Bendix reputation in ignition has been spotlighted by scores of important engineering firsts, the industry's wide acceptance of Bendix ignition equipment has been built largely on the solid foundation of product excellence in every component part.

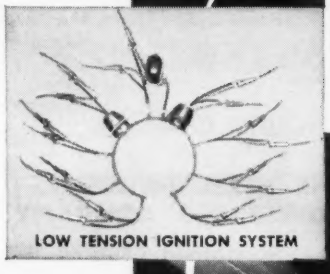
Just as a chain is no stronger than its weakest link, dependable ignition is the result of components designed and manufactured for unfailing efficiency.

That's why it pays to insist on Bendix ignition components for every part of your ignition system. Whether your requirement is for a better electrical connector, a complete new ignition system, or the famous Bendix Ignition Analyzer, you can be sure of quality performance when the good name of Bendix safeguards the reputation of every individual ignition product.

Why not consult our sales department for details?

AVIATION PRODUCTS

Low and high tension ignition systems for piston, jet, turbo-jet engines and rocket motors . . . ignition analyzers . . . radio shielding harness and noise filters . . . switches . . . booster coils . . . electrical connectors.



LOW TENSION IGNITION SYSTEM

IGNITION ANALYZER

ELECTRICAL CONNECTOR

Bendix

SCINTILLA MAGNETO DIVISION

SIDNEY, NEW YORK

Export Sales: Bendix International Division
205 East 42nd St., New York 17, N. Y.

FACTORY BRANCH OFFICES: 117 E. Providencia Avenue, Burbank, California • Stephenson Building, 6560 Cass Avenue, Detroit 2, Michigan • Brouwer Building, 176 W. Wisconsin Avenue, Milwaukee, Wisconsin • 582 Market Street, San Francisco 4, California

KEARFOTT COMPONENTS

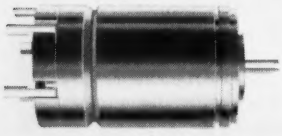
—essential for modern controls

(shown 1/4 size)

GYROS

Vertical, Free and Rate Gyros provide the utmost in performance under extreme environmental and operational conditions. Hermetically sealed in dry, inert gas, these Gyros are characterized by compactness, vertical accuracy and low drift rates. They are accepted as the standard in airborne radar, camera stabilization and missile guidance applications.

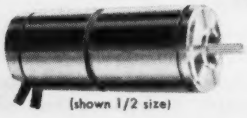
SYNCHROS



(shown 3/4 size)

For use as transmitters, control transformers, repeaters, resolvers and differentials. Synchros with maximum diameter of 1 1/16", available from production, with maximum error of seven minutes of arc. Unique design eliminates rotor to stator eccentricity errors and provides dependable service under extreme environmental conditions.

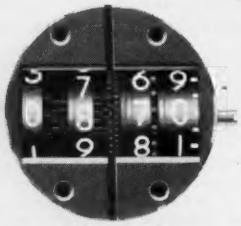
SERVO MOTORS



(shown 1/2 size)

High torque—low inertia servo motors are available in ranges from 31/32" to 1 3/4" in diameter. Also integral combinations including damping and computing tachometers. Geared servo motors, in the same diameters, can be provided to meet the highest performance.

OTHER PRODUCTS



(shown full size)

In addition to the precision Angle Counter shown, many other mechanical and electromechanical devices are available from regular or special production. Kearfott's long years of experience in the design and production of precision instruments and components are at your service.

Bulletin #53 describes the many services, components and products the Kearfott Organization offers you. Write for a copy TODAY

KEARFOTT COMPONENTS INCLUDE:

Gyros, Servo Motors, Synchros, Servo and Magnetic Amplifiers, Tachometer Generators, Hermetic Rotary Seals, Aircraft Navigational Systems; and other high accuracy mechanical, electrical and electronic components.

Kearfott

SINCE 1917

CREATIVE ENGINEERING
PRODUCTION ACHIEVEMENT

KEARFOTT COMPANY, INC., 1150 McBride Ave., Little Falls, N. J.
Midwest Office: 188 W. Randolph St., Chicago 1, Illinois
West Coast Office: 253 N. Vinedo Ave., Pasadena, Calif.
A General Precision Equipment Corporation Subsidiary

roofs of some 700 of its warehouses at bulk plants throughout the Pacific West. Although most of these signs were removed during World War II for security reasons, they were restored as plants were repainted.

Through the efforts of its research organization, known as California Research Corporation, a large portion of whose activities have been devoted to aviation, Standard has pioneered in the development of high-octane fuels, jet fuels, compounded aviation oils, nonflammable hydraulic fluids, special aviation greases for performance at extreme temperatures such as encountered at high altitudes, etc.

Important contributions to aviation have resulted and from all indications should continue in the future.

STANDARD OIL COMPANY (INDIANA)

Chicago, Ill.

The Standard Oil Company (Indiana), as the first large company to sell motor gasoline containing TEL,* helped establish the trend to high-octane fuels. The other premium components—synthetic hydrocarbons—evolved from the company's Burton cracking process.

Standard was the first to own a multi-engined executive airplane, Ford Tri-Motor No. 6 with Wright J-4 engines. The company and its affiliates now operate 23 executive planes.

Pioneering of 100-octane gasoline itself was done by Shell. Through committee work and through its own research, Standard contributed to this development. The company was especially active in producing aromatics and made important advances in the fields of isomerization and fluid catalytic cracking.

Toward the end of World War II, the company's refineries were making more 100-octane gasoline than was available to Goering's Luftwaffe. Today the company is again making aviation gasoline on an "all-out" basis.

Standard Oil Company (Indiana) is proud of its supporting role in the drama of aviation. It salutes the pioneers who flew the first powered airplane. It also salutes those who have developed the airplane into a major means of transportation and a powerful weapon for national defense.

* Tetraethyllead.

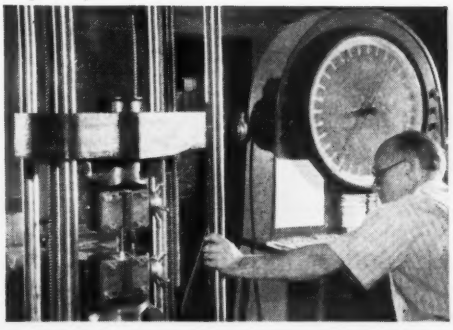
THE STEEL PRODUCTS ENGINEERING COMPANY

Springfield, Ohio

The Steel Products Engineering Company is a pioneer in the field of aeronautical engineering research, develop-

more performance per pound with new alloy aluminum extrusions

Harvey Aluminum has developed a new aluminum alloy having typical ultimate mechanical properties of 100,000 PSI. Guaranteed properties are above those of any aluminum extrusion alloy yet developed. Long range research at Harvey has produced the best possible alloys for high stress structural application. Mechanical properties of this new alloy, HZM100, are higher than any other aluminum alloy. Another feature of HZM100 of particular interest to structural engineers is its satisfactory stress corrosion resistance.



Proving tensile strength of test specimens in all aluminum alloys is part of the quality control carried on continuously at Harvey Aluminum.

MAKING THE MOST OF ALUMINUM . . FOR INDUSTRY

HARVEY Aluminum

HARVEY ALUMINUM SALES, INC.
TORRANCE • LOS ANGELES, CALIFORNIA
BRANCH OFFICES IN PRINCIPAL CITIES

An independent facility producing special extrusions, pressure forgings, bar stock, forging stock, tubing, aluminum screw machine products, and related mill products.

ment, and manufacturing. Beginning as a small shop engaged in machining and engineering in 1908—the year the Wright brothers received their first airplane contract from our Government—the company practically grew up with the aircraft industry and has to its credit 45 years of dependable service.

Changes and expansions have elevated it to many times its original size. It now has 300,000 sq.ft. of manufacturing floor space. It employs 1,400 skilled workers. Its high capacity for precision manufacturing is supplemented by extensive research, engineering, and testing laboratories.

Broadly classified, current production covers: precision gear assemblies, helicopter transmissions, bomb hoists, aircraft gun turrets, landing-gear struts, propeller hubs, jet-engine components, radar lens and gearing assemblies, and aircraft fueling accessories. Many of these were completely developed within Steel Products' plant.

Since 1908 Steel Products has kept abreast of the times, with many "firsts" to its credit in development and processing. Its capabilities are evidenced by the outstanding aircraft companies repeatedly served.

The company is still headed by its original founder, J. E. McAdams. C. P. Meredith is Executive Vice-President; C. J. Gano, Vice-President—Manufacturing; D. L. Getz, Vice-President—Engineering; R. B. Yirak, Secretary; and W. M. Jordan, Sales Manager.

STROUKOFF AVITRUC

Stroukoff Aircraft Corporation

OF WEST TRENTON, N. J.

Stroukoff is back again in the field of aeronautical research and development.

•

The United States Air Force has just transferred an important development contract from Chase Aircraft Co. to Stroukoff Aircraft Corp.

•

Work now being performed at the same address where it was done before with additional space in a new building in actual construction NOW.

•

The entire staff of engineering and production personnel which has been with Mr. Stroukoff for many years is with Stroukoff Aircraft Corporation and looks forward happily to its new endeavors.

•

In addition, the Company announces that Captain John W. King, U. S. Navy (Retired) has joined it in helping to provide our Nation with better aircraft.

•

We are open for engineering work, contracts or sub-contracts.

STROUKOFF AIRCRAFT CORPORATION

West Trenton, N.J.

The Stroukoff Aircraft Corporation, of West Trenton, N.J., incorporated in August, 1953, under the laws of the State of New York, is continuing with a comprehensive program of research and development which already has made its President and Chief Engineer, Michael Stroukoff, a widely known figure in the aviation world.

In his relatively brief career in the field of aeronautics, Mr. Stroukoff has concentrated on the design and development of cargo aircraft. In 1947, he built and flew the first all-metal cargo glider in aviation history, the G-18. Under a subsequent contract from the U.S. Air Force, he transformed the G-18 into a twin-engined cargo plane, the C-122, America's first assault transport, capable of landing in and taking off from rough, unimproved fields with troops and materiel. This success in the assault transport class caused the Air Force to abandon the concept of glider support for military units operating in forward combat areas.

Stroukoff engineering also produced a bigger and better assault transport design that accomplished the unprecedented feat of flying as a glider (G-20) as a plane with conventional piston-engined power (XC-123), and as the first American-developed jet-powered transport (XC-123A).

In Assault Transport Evaluation Tests conducted by the Air Force in 1950, the C-123 emerged with top honors and the C-122 was second in competition with several other design entires.

The emphasis in Stroukoff Aircraft Corporation is on balance and versatility. Men of demonstrated engineering and administrative talent, many of them high-caliber experts in aerodynamics, helicopters, guided missiles, hydroplanes, etc., whose association with Mr. Stroukoff dates back to his early days in the industry, are continuing with him in the new corporate venture.

STURGESS, INC.

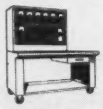
Glendale, Calif.

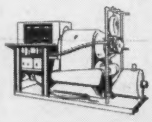
Sturgess, Inc., since 1939 has been vitally concerned with aircraft control and testing devices.

Pacific Scientific Company, 1430 Grande Vista Ave., Los Angeles, handles

United

ELECTRICAL TESTING EQUIPMENT





Electrical components on aircraft, portable power units, ordnance vehicles and guided missiles are tested rapidly and accurately with United Test Equipment.

Our products meet the most critical requirements of the Armed Forces of the U.S., electrical equipment manufacturers and major airlines of the world.

Your inquiries are cordially invited—promptly answered.

UNITED MANUFACTURING CO.

HAMDEN 14 CONNECTICUT

Since 1910 American Tube Bending has played a notable part in the development of powered flight. We have seen the piston engine grow from the early in-line and radial types to the complicated monsters of today. Our parts were on the earliest jets. We have passed the sonic barrier on rocket engines. Light planes, propeller and jet fighters, big bombers and transports all fly with ATB components in exhaust systems, engine mounts, fuel, hydraulic and air lines.

Over forty years of experience in the fabrication of tubular assemblies of all kinds from the smallest to ducting of 4½" O. D. x .035" tubing, back up our work. Our engineers will be glad to help you in money-saving design and production.

AMERICAN TUBE BENDING COMPANY, INC.

5 Lawrence Street
New Haven 11, Connecticut

Who could blame a person for having murder in his heart. After laboring over a drawing for hours, suddenly there's an unexpected blob of ink, and in a flash the drawing is ruined.

That's why it pays to specify Arkwright Tracing Cloth. Careful manufacture assures a working surface free of heavy threads, pinholes, and other imperfections that can lead your pen to disaster.

Arkwright Tracing Cloth is fortified, too, to take all the erasing you'll normally ever give it. Erase . . . and ink again. Lines will still come out sharp and clear — without "feathering". That's why Arkwright Tracing Cloth is ideal for good, readable blueprints.

Want to be convinced? Write for a free sample. Arkwright Tracing Cloth will convince you, just as it has thousands of others, it's truly America's Standard". Arkwright Finishing Co., Industrial Trust Bldg., Providence, R. I.

ARKWRIGHT
Tracing Cloths
AMERICA'S STANDARD FOR OVER 32 YEARS

all sales and service of Sturgess products.

One product Sturgess manufactures is aircraft regulators. This is a device, variable in size and mechanical in operation, which is built into an aircraft structure to maintain adequate tension in the various control systems—aileron, rudder, elevator, or throttle. Sturgess regulators compensate for natural plane deflection affecting control cable systems.

To measure accurately cable tension to avoid overtension or slack, another product, the Sturgess Tensiometer, is the favorite with maintenance men and rigging crews. Several models are available, including one specifically designed for cold-weather use with service mittens. Cold or heat does not affect the accuracy of the instrument.

Sturgess, Inc., also makes the Speed-Rig, a device that replaces standard turnbuckles in a cable system. With Speed-Rig a man can disconnect and re-rig a control cable to an exact tension in seconds. No tools are needed for installation or tension adjustment.

Sturgess, Inc., also manufactures seat locks and a multidirectional harness reel that protects a pilot against injury in case of sudden shock. Accelerometers, potentiometers, program timers, and other electrical control devices are also manufactured by Sturgess.

SUMMERS GYROSCOPE COMPANY

Santa Monica, Calif.

Since World War II, Summers Gyroscope Company has produced over 22,000 automatic control systems for pilotless aircraft. Summers has coined the name "gyro servo" to describe flywheel-type force servos in which the flywheel is gimbaled to sense angular rate. Gyro servos, a Summers invention, are used as yaw dampers in aircraft and missiles. Summers first installed yaw dampers into aircraft in 1945; later, Summers installed damper servos in such missiles as the Hughes TIAMAT and the Boeing GAPA. Summers recently introduced low-cost gyroverticals into the control field, obsoleting expensive conventional gyroverticals by utilizing airplane sensitivity to gravity, thereby eliminating costly gravity-sensitive erecting apparatus. Thousands are now used to establish a vertical reference for aircraft and missile autopilots.

A new Summers-developed integrating motor simplifies control systems and eliminates tubes from Summers autopilot developed for All-Weather Flying Division, WADC. Dynamic performance is unparalleled, torque/inertia ratio being 1,000,000 rad. per sec. per sec. and acceleration time constant being 3 millisec.

Summers specializes in dynamic analysis and control system design, producing its own autopilot components. Among its 400 products are several missiles, gyroscopically stabilized, and a new control system for the giant TARZON bomb.

TELECOMPUTING CORPORATION

Burbank, Calif.

Founded and staffed by engineers from the aircraft industry, Telecomputing Corporation has specialized in solving data-reduction and computing problems, particularly those encountered in fields of aviation. Today Telecomputing manufactures a wide range of data-reduction instruments, in addition to conducting its computing service.

Two recent developments are typical of Telecomputing's efforts to develop faster, more accurate methods of data reduction:

The Contact Telereader edits, reads, and calibrates oscillograms. It presents its results in visual form and operates electronic readout equipment to record results in typewritten lists, perforated tape, or punched cards. Electronic "packaging" enables users to assemble data-reduction systems suited to their needs without adding superfluous components.

The Dial Reader enlarges 35-mm. pictures of instrument panels, projects the images on a screen, and converts dial or needle angles into digital form for recording on typewritten lists, perforated tape, or punched cards. The film may be either advanced one frame at a time for close analysis or animated for editing, backward or forward.

THE H. I. THOMPSON FIBER GLASS COMPANY

Los Angeles, Calif.

The H. I. Thompson Fiber Glass Company is a leading manufacturer of high-temperature insulation products for the aviation industry.

Extensive research and experimentation by this company led to the development of "Ref'rasil," a refined fibrous silica product, providing maximum insulation efficiency up to 2,000°F. with less than one-half the weight and bulk of comparable materials. In a typical application, a temperature drop of approximately 900°F. is accomplished in a blanket thickness of $\frac{1}{2}$ in.

The development of Ref'rasil Lightweight Removable Insulating Blankets by "HITCO" has been an outstanding contribution for efficient insulation against high temperatures in jet aircraft engines. The searing heat generated by the supersonic speed of today's planes requires special insulation protection. Ref'rasil blankets provide this protection with light weight, easy removal, and high insulation efficiency. Today, Ref'rasil blankets are specified by more than 90 per cent of the manufacturers of jet-powered planes.

Photo shows physical forms of Ref'rasil high-temperature insulation. This is available in bulk fiber, batt, cloth, cordage, sleeving, and tape.

Thermo-Cousti is another product of The H. I. Thompson Fiber Glass Company that is finding increasingly wider use throughout the aviation industry. This product is also used in the fabrication of many types of insulating blankets for sound and low-temperature applications. Thermo-Cousti blankets provide maximum comfort for aircraft passengers and crew by efficient insulation of cabin and cockpit interiors against noise, heat, and cold. Preformed duct covers are also produced by HITCO for hot-air, cold-air, and deicer systems.

The efficiency and versatility of both Ref'rasil and Thermo-Cousti are finding for these products many new aviation applications where critical conditions require a high-performance insulation material.

In addition to the main plant at 1733 Cordova St., Los Angeles, the company has established completely equipped producing facilities in Canada at Guelph, Ontario.

HITCO's Design and Development Department welcomes the opportunity to cooperate in the solution of specific or unusual insulation problems, either of a thermal or electrical nature.

THOMPSON PRODUCTS, INC.

Cleveland, Ohio

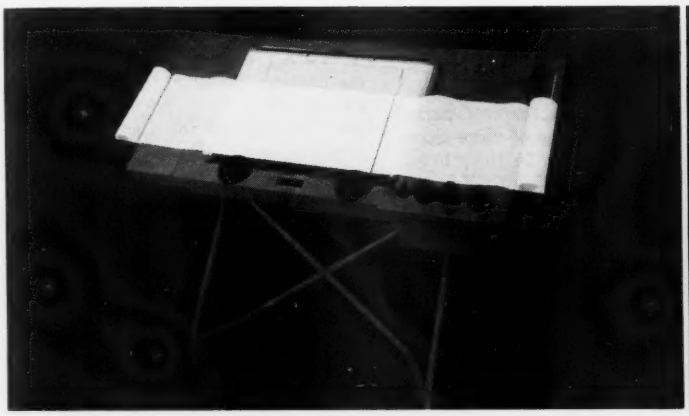
Thompson Products has grown up with the American aircraft industry, and today it is one of the nation's largest manufacturers of components and accessories for jet engines, as well as one of the largest suppliers of parts and accessories for piston-type aircraft engines.

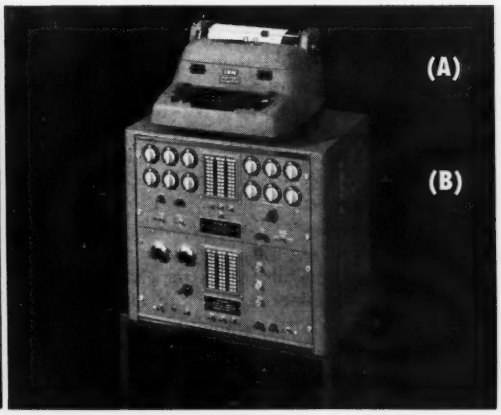
Telecomputing announces:

the first low-cost data reduction system

Everyone concedes the value of modern data reduction instruments; but not every organization feels it can "afford" them—just yet.

A pioneer in the field of data reduction, Telecomputing has long sought a solution to this problem. It now presents the first low-cost data reduction system which offers speed, accuracy and flexibility at a price most organizations can afford: $5,555.





1 **The Contact Telereader** **$2195**

measures oscillograms and other graphic records. It handles single sheet or roll records—any length, any width up to 18"; performs linear and non-linear calibrations; provides accuracy to .01" per count; permits up to 40 measurements per minute by means of X-Y crosswires.

Operates Alone

The Contact Telereader also can be used independently of the data reduction system to perform rapid, accurate measurements. Readout, however, must then be made by manual methods.

Engineers—Telecomputing offers you a future in fields of the future—data reduction, computing, and the solution of mass record-handling problems for Business.

2 **The Teleducer** **$1690**

electronically converts Contact Telereader measurements into digital form.

Other Teleducer Applications

The Teleducer can be used by itself as a laboratory digital voltmeter with an accuracy of 0.1%. It can also be used independently to digitize output of strain gauges and thermocouples without D. C. amplification. It provides for minimum full-scale input of 10 millivolts (10 microvolts per count) and maximum full scale input of 1.0 volt without external attenuation.

The Teleducer and accompanying Program Unit are housed in the same cabinet.

3 **Electric Typewriter (A)** **$920**

The Program Unit (B) **$750**

prepares parallel digital data for serial readout to the electric typewriter shown on top of the Teleducer-Program Unit cabinet.

Readout can also be in punched cards or punched tape.

Specifications on the new data reduction system, as well as detailed information showing how the Contact Telereader and Teleducer can be used independently, will be mailed you upon request. Coupon is for your convenience.

TELECOMPUTING CORPORATION

BURBANK, CALIFORNIA **WASHINGTON, D. C.**

Turn hours into minutes with automatic data analysis

Mr. Preston W. Simms, AER-12
Telecomputing Corporation, Burbank, California

- ☐ Please send me specifications on the data reduction system.
- ☐ Please send me specifications showing how the Contact Telereader can be used alone.
- ☐ Please send me specifications showing how the Teleducer can be used alone.

Name

Company

Street Address

City and State

DEPARTMENT OF TECHNOLOGY
BUFFALO PUBLIC LIBRARY

An early and highly significant contribution of the company was its part in perfecting the design and manufacturing techniques of the sodium-cooled valve. Later, valve steel alloys such as TPA, TPM, and others introduced by Thompson Products aided materially in the successful development of the modern high-powered piston-type aircraft engines.

By the time World War II began, Thompson Products had designed and was supplying aircraft engine-driven fuel pumps. A major contribution of the company to high-altitude flying was the development and introduction of the fuel booster pump, which is mounted on the fuel tanks and scours the air and vapor bubbles out of gasoline to prevent vapor-lock. Other components being manufactured were turbosupercharger blades and wheels, fuel selector cocks, exhaust manifold sleeves, and a host of hardened and ground parts for aircraft, in addition to its well-known valves.

With its years of experience in shaping tough and hard metals to extremely close tolerances and doing the job in large quantities, Thompson Products was prepared to undertake the new and difficult task involved in producing parts for jet engines when they entered the picture. The company soon replaced costly and time-consuming machinery and grinding operations required on jet-engine blades and buckets with precision forging and other processes that resulted in high production rates and lowered costs.

Paralleling this activity, Thompson sponsored the development of the TP-1 powder-metal compressor blade, which is unique in the industry, and millions of this type of blade have been produced. The frozen mercury process for precision casting of difficult parts was also perfected and placed in large-scale production, particularly useful for advanced designs of hollow turbine buckets and wave guides.

Although Thompson is a major producer of the complete compressor stator, compressor rotor, turbine nozzle, and turbine wheel assemblies, it has continued to make precision parts for reciprocating engines and has pioneered in developing other aircraft components and accessories. For example, it is a leading supplier of air turbine-driven afterburner pumps, water-injection pumps, and high-pressure gear-type fuel pumps.

Recently, Thompson has entered the aircraft electronics field, producing antennas, coaxial switches, and allied electronic equipment.

Extensive research and development programs in central staff and all divisions is a basic company policy and from these can be expected to come new and important contributions to the aircraft industry.

TINNERMAN PRODUCTS, INC.

Cleveland, Ohio

Combining light weight and low unit cost and effecting vast savings in materials handling and assembly time, job-engineered SPEED NUT* brand fasteners, made by Tinnerman Products, Inc., are consistently providing the correct solutions to many challenging light assembly problems in the nation's aircraft industry.

Because of the extreme ease and speed with which these spring-tension fasteners may be assembled, many aircraft manufacturers have standardized parts from the Tinnerman line of more than 8,000 types of fasteners in their light assembly operations.

One major aircraft manufacturer, for example, found that by standardizing a Tinnerman SPEED CLAMP designed to secure electrical wire harnesses, he was able through greatly reduced installation costs to realize a savings of 18 cents per clamp over a former method.

The unique clamp, incorporating a special latching feature that permits it to be opened and closed without removal from the structure to which it is attached, effected further timesavings owing to the ease and speed with which cable bundles could be removed and replaced on undelivered aircraft at modification depots.

Another large aircraft manufacturer, using U-Type SPEED NUTS, was able to save 448 man hours per plane on a single fastening application.

Replacing twelve parts formerly used, the SPEED NUTS, used to install cargo liners, brought about an 80 per cent reduction in production time and lowered materials handling time by 40 per cent.

Moreover, the use of this U-Type SPEED NUT eliminated an entire assembly section releasing several skilled workers to other production jobs.

These instances are but two of thousands of cases in which Tinnerman job-engineered SPEED NUT brand fastenings are solving perplexing problems and effecting astounding cost savings in aircraft assembly operations.

* Trade Mark Registered.

TRANS WORLD AIRLINES, INC.

New York, N.Y.

A major milestone in the early days of commercial aviation was the first flight of passengers by a scheduled air line across the United States. The initiative, imagination, and skill of the pioneer airmen in Trans World Airlines' predecessor companies made possible this primary step toward public acceptance of air transportation.

With the experience gained in the Ford and Fokker years, TWA helped develop the first efficient modern air liner, the DC-1, prototype of the famous DC series.

Engineering progress was concomitant with meteorological research. TWA organized an air-line weather department with a professional meteorologist, and it soon applied scientific air mass methods of weather analysis in its operations.

High-altitude experimental studies in weather and flight characteristics led to TWA's development of the anti-rain-static "homing" radio direction finder. Data that proved valuable in the development of the turbosupercharger were gathered. Cooperative research projects resulted in the development of deicers for wings and propellers.

Advanced techniques evolved in the mid-thirties were applied in 1940 when TWA helped develop and use in transcontinental service the first four-engined pressurized cabin transports—Boeing Stratoliners—for overweather flying and passenger comfort. Flight engineers became part of the skilled team on the new four-engined aircraft on U.S. routes.

The complexities that accompanied the widening horizons in speed, range, and altitude required broader weather knowledge. In 1941, an all-weather flying research staff, including ground and pilot personnel, and a special "flying laboratory" to study thunderstorm activity searched the skies.

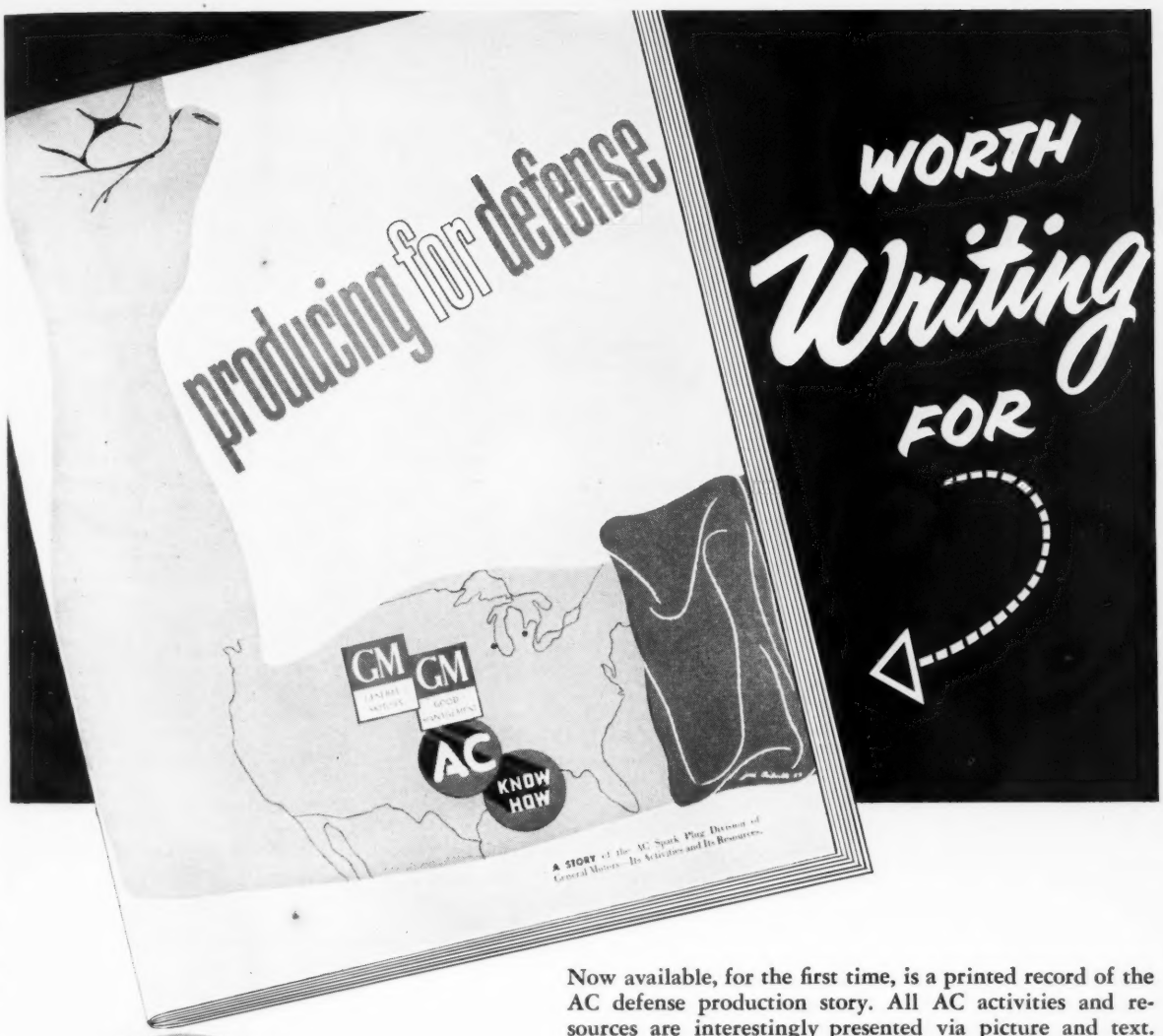
New doors in meteorology, navigation, and mechanical operation were opened during World War II when TWA operated over-ocean flights around the world for the Armed Forces. TWA pilots, trained in celestial navigation, pioneered the now commonplace "pressure pattern" flying system.

In the postwar period, a new luxury-type 300-m.p.h. transport—the Constellation (a TWA-Lockheed project)—was put into scheduled service on United States and transatlantic routes.

TWA's operational sights continue to be trained on the prime factors of increased public acceptance of air travel—dependability, efficiency, and low fares. Today, TWA is the lowest-cost operator in transatlantic flying and the world's leading operator of low-fare Sky Tourist flights.

With the Constellation the backbone of our fine fleet, the immediate tomorrow holds a further technologically advanced version, the 1049E turbocompound version. TWA has ordered eight of these with an option for twelve more.

TWA continues to look toward future progress in the field of turboprop trans-



Now available, for the first time, is a printed record of the AC defense production story. All AC activities and resources are interestingly presented via picture and text. Through it you can become quickly acquainted with the physical facilities, manpower, training programs and production achievements of this Division of General Motors. Get your copy soon and discover how the "know how" and experience AC has accumulated in the past can be projected into the future . . . perhaps in your behalf! AC is now producing — in volume — these complex, high-precision, electro-mechanical devices for the Armed Forces:

- **"A" Series Gun-Bomb-Rocket Sights**
- **A-1A Bombing Navigational Computers**
- **T-38 Fire Control System for the Skysweeper**

AC QUALITY PRODUCTS

DEFENSE PRODUCTS
of High Quality at Low Cost
DELIVERED ON TIME

AC SPARK PLUG DIVISION GM GENERAL MOTORS CORPORATION

MAIL THIS COUPON TODAY

Name_____

Title_____

Firm_____

Street_____

City_____ Zone____ State_____

AER

DEPARTMENT OF TECHNOLOGY
BUFFALO PUBLIC LIBRARY

ports. The jet transport will arrive, too, when it has achieved the standards on which TWA and all other U.S. air lines operate—safety, versatility, economy of operation, and reliability.

RALPH S. DAMON, *President*

UNION CARBIDE AND CARBON CORPORATION

New York, N.Y.

Union Carbide and Carbon Corporation, through its extensive research over the years in alloys and metals, carbons, chemicals, industrial gases, and plastics, has made many important contributions to aviation progress. These have included not only the development of special materials to combat the extreme conditions under which aircraft operate but also the working out of special fabricating processes—such as precision investment casting and high-speed welding—which have made possible rapid mass production of aircraft parts.

It was in the late 1920's, for instance, that Union Carbide introduced a series of alloys specially designed to combat extreme heat, corrosion, oxidation, and wear. About the same time, the Corporation also pioneered in the development and use of the alloying metal columbium to improve the strength of stainless steels and other metals used in high-temperature applications. Then, when jet plane developments showed a need for metals that would withstand higher temperatures and stresses, the Union Carbide laboratories responded with a dozen or so new superalloys that have given exceptional service in many vital aircraft parts, and there are several now in the development stage which have even better properties than the high-temperature materials in use today. Among the numerous applications of these alloys are tail cones, turbine buckets, engine hoods, combustion chambers, nozzle vanes, collector rings, valves, and cabin heaters.

UNITED AIR LINES, INC.

Chicago, Ill.

Numerous contributions to the general development of aviation have been an important concomitant in the growth of United Air Lines which, dating its operations from April 6, 1926, is the nation's oldest air line.

A random sampling of the many "firsts" established in its 27-year history shows that United was first to develop a practical set of wing deicers, first to install hydramatic full-feathering propellers, first to test a low-tension ignition system on R-2800 engines. In 1929 the company developed two-way, plane-to-ground voice radio, a project that communications experts of the time had written off as hopeless.

Mainliners and Cargoliners undergo major overhaul at company's "push-button" maintenance base adjoining San Francisco's Municipal Airport.

United initiated development of the DC-4, opening negotiations with Douglas Aircraft Company, Inc., in 1935. Production of the prototype later became a cooperative undertaking, with four other air lines invited to participate. Through vigorous support of the project and perseverance in the face of discouraging delays before World War II, United is to a large degree responsible for the fact that the C-54 became available for its wartime role.

Indicative of the company's status as a fountainhead of technological advances, tool index records for the last 10 years reveal that almost 5,000 new tools have been designed and placed in use at United's "push-button" maintenance base. The base, adjoining San Francisco's municipal airport, is regarded as one of the most modern and efficient overhaul plants in the aeronautical world. Approximately 3,000 mechanics, technicians, and engineers are employed there under the direction of J. A. Herlihy, Vice-President—Engineering and Maintenance.

The Engineering Department at the "push-button" base has four divisions—engineering planning, service engineering, flight engineering, and aircraft engineering—all headed by W. C. Mentzer. A Technical Development Division, with R. D. Kelly as Superintendent, evaluates new aircraft and related devices. An Engineering Test Center, used in developing special equipment not available from manufacturers, has yielded such items as the rotating red navigation light, which has been adopted as standard by United and several other air lines.

United has 14,500 employees at 78 cities on a 13,250-mile system, extending from the Atlantic to the Pacific, the length of the Pacific Coast from San Diego to Vancouver, and from California to Hawaii. The company's present fleet of 170 twin- and four-engined planes includes DC-3's, DC-4's, DC-6's, DC-6B's, Convair 340's, and Boeing Stratocruisers. Delivery of 55 Convair 340's, which began in 1952, will be completed in 1954. United also has 25 DC-7's on order, with delivery to start in 1954.

The company's operating base is at Denver; its executive headquarters are at Chicago. W. A. Patterson is President.

UNITED AIRCRAFT CORPORATION

East Hartford, Conn.

United Aircraft Corporation consists of four divisions, each a pioneer in its own field.

Pratt & Whitney Aircraft, the largest of these divisions, with its development of the air-cooled engine and more recently its design and manufacture of high-performance axial-flow gas turbines, has made vital contributions for almost 3 decades to the nation's air power and the world's air commerce.

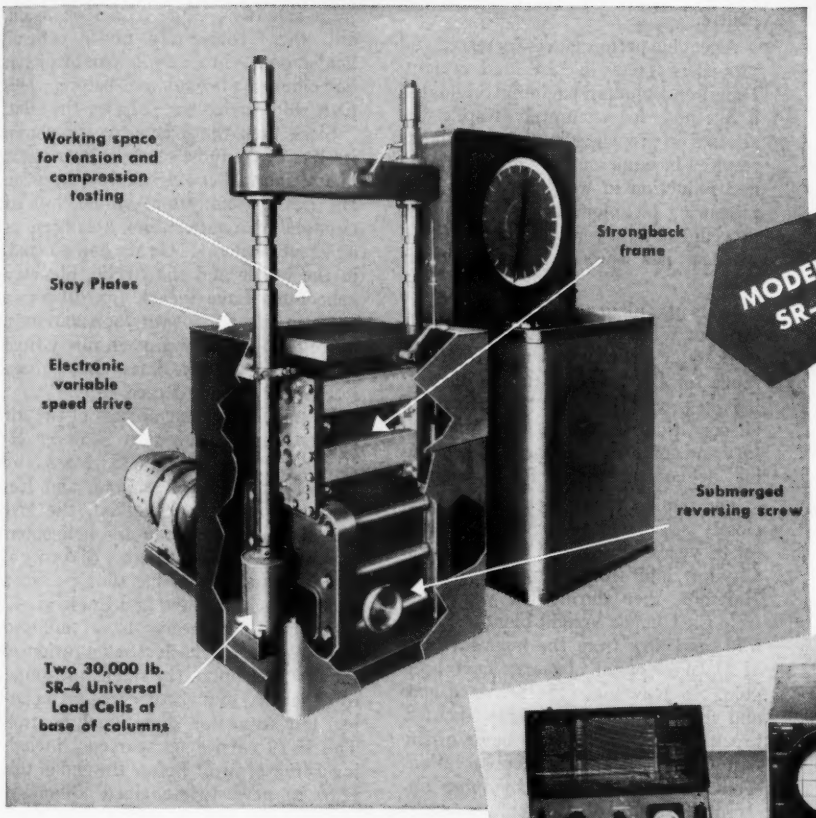
Hamilton Standard and its predecessor companies pioneered the metal propeller, and through creative engineering of the propeller and its modern devices has made possible the full utilization of the aircraft engine's phenomenal growth.

Chance Vought, more than 25 years ago, designed and built a two-place observation biplane, the first "Corsair," powered with the first Pratt & Whitney Wasp. This airplane outperformed the fighters of that day, established four world's records, and provided new horizons for Naval aviation, while demonstrating to all the military services what compact and dependable horsepower could do for an airplane and, in turn, what a good designer could accomplish once he had available the appropriate horsepower.

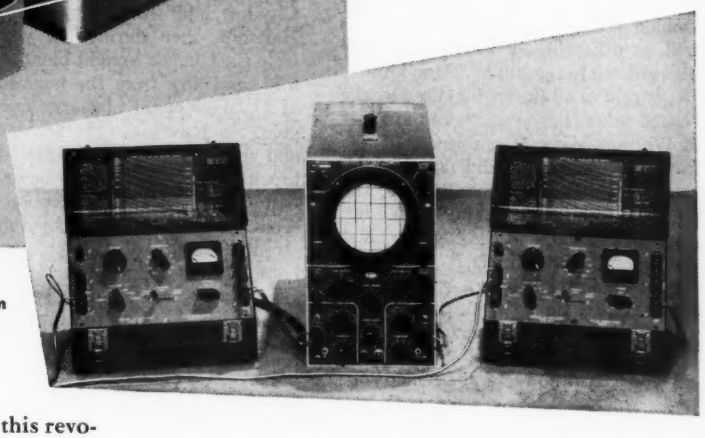
Sikorsky Aircraft has created new vistas in widely diverging fields. Its flying boats pioneeered transoceanic flying, and the helicopter, which it pioneered, has saved literally thousands of lives in the brief period since the division, under the engineering guidance of Igor I. Sikorsky, designed and built the first practical helicopter in this country.

"United Aircraft and its divisions are primarily engineering organizations and have been from their birth," Frederick B. Rentschler, Founder and Chairman, said recently. Of the corporation's 55,000 employees, more than 10,000—about 20 per cent—are in the engineering departments. The corporation has a research department with its own extensive laboratories and the largest privately owned wind tunnel in the world, where problems of airflow and heat control are being studied for results, the practical applications of which

NOW! A Machine Fast Enough for SHOCK Tests on Structures


Working space for tension and compression testing
Stay Plates
Electronic variable speed drive
Strongback frame
Submerged reversing screw
Two 30,000 lb. SR-4 Universal Load Cells at base of columns

MODEL FGT BALDWIN-EMERY SR-4 TESTING MACHINE



Oscilloscope X-Y diagram system records stress-strain curves in shock testing

The extraordinary high speed of response of this revolutionary new Baldwin-Emery universal testing machine, paired with an oscilloscopic X-Y diagram, enables it to measure and record shock tests on complete structures. Its SR-4 load cells and SR-4 type extensometer make it capable of responding to the rates required by shock conditions.

The load cells and extensometer feed signals to the oscilloscope through pre-amplifier circuits. An instantaneous stress-strain curve and its two axes then appear on the oscilloscope screen. It is possible to have this screen photographed continually to record changes in the shape of the stress-strain curve as the structure itself changes.

Its unique aptness for such shock tests is one of the reasons why the FGT SR-4 Testing Machine is being recognized as *the greatest advance in materials testing equipment in twenty years.*

Full details on this latest contribution of Testing Headquarters are in Bulletin 4202. For your copy, write to Dept. 2201, Baldwin-Lima-Hamilton Corporation, Philadelphia 42, Pa.

BALDWIN BLH LIMA-HAMILTON

TESTING HEADQUARTERS

BALDWIN-LIMA-HAMILTON

General Offices: Philadelphia 42, Pa. • Offices in Principal Cities

may not make their appearance for many years. At Pratt & Whitney Aircraft, the huge test cells built 10 years ago for experimental engines (once referred to as "dinosaur houses") are dwarfed today by the Andrew Willgoos Laboratory, where four great boilers for big ocean-going vessels and twelve marine turbogenerators provide the power and pumping facilities required in the testing of jet engines.

This recognition of the importance of engineering and development and the emphasis that has been placed continuously on it account in a large measure for the creative achievements of all of United's divisions.

Pratt & Whitney Aircraft moved at once into a commanding position in the engine field with its first power plant, the 425-hp. radial air-cooled Wasp. The Wasp was quickly followed by the more powerful Hornet, and as development continued both engines increased in horsepower.

By 1935, 10 years after the engine company was founded, horsepower had been more than doubled, and when World War II came upon the country, Pratt & Whitney was ready with the Double Wasp, delivering 2,000 hp., as well as other highly developed power plants down to the 500-hp. class. About 50 per cent of all the engines used by the United States in the war bore the Pratt & Whitney Aircraft emblem, but the war and its problems did not stop development. Before combat ended, the military fliers were taking 3,000 hp. from the R-2800, and the engineers had developed the 28 cylinder R-4360 Wasp Major, the world's most powerful piston engine, rated up to 3,800 hp. and in daily use now in bombers and transoceanic transports.

Its concentration on war demands delayed Pratt & Whitney's entrance into the gas-turbine field until 1946. Nevertheless, after embarking on a program of high-power axial-flow gas-turbine development, the division is now in full production on its J-57, an unmatched engine with the greatest power and most economical fuel consumption of any available gas turbine here or abroad in the same period. Pratt & Whitney Aircraft has also developed the T-34, a 5,600-hp. propeller turbine, the most powerful of its type known to be flying.

Hamilton Standard has paralleled Pratt & Whitney's engine story in creative engineering, development, and production of the propeller. In 1933, Hamilton Standard won the Collier Trophy for the development, under the guidance of Frank Caldwell, of the controllable-pitch propeller, a paramount contribution to the range and safety of both military and commercial aircraft. Then came the "constant-speed" propeller, a veritable automatic "gear shift of the air."

During the war, 75 per cent of Allied combat, transport, and advanced training aircraft bore the Hamilton Standard label, and today 90 per cent of the world's commercial transports are equipped with Hamilton Standard propellers.

As engine performances increased and propellers grew in size and weight, Hamilton Standard engineers originated a method for accurately testing the stresses on propellers in flight which has resulted in immeasurably greater safety and reduction in weight. This stress-measuring technique is now a required procedure by the services and the CAB. Its use has spread to many other fields.

In its new plant and extensive laboratories at Windsor Locks, Hamilton is at work today on propellers in the transonic range for the propeller-turbine engine; it is in production on refrigerating and air-conditioning systems for both military and commercial planes and is building fuel control systems for jet engines.

The name Chance Vought has been closely associated with Naval aviation for 36 years. First from a Long Island City loft, later from a new plant in East Hartford, then during the war years from the Chance Vought plant at Stratford, and now from the huge facilities at Dallas, Vought airplanes have been going to Naval establishments ashore and afloat year after year without a break. Mention has been made of the first Corsair, a two-place observation-scout. It was followed by more observation-scouts, dive bombers, scout bombers, and trainers until World War II. Vought contributed several airplane designs during the war, but then concentrated on the last of the Corsairs, the inverted gull-winged fighter, characterized by the Navy in 1940 as "the fastest plane in this country." Built around the Pratt & Whitney Double Wasp, utilizing the Hamilton Standard Hydromatic, this aircraft was an all-United Aircraft product.

It saw service in the Pacific, both aboard carriers and as the fighter-bomber of the Marine Corps. It became standard equipment aboard British carriers, and as this is being written it is still holding its own with the newer jets as a close support ground attack bomber for the Marines in Korea. Vought started production on this aircraft in 1941, and the final Corsair (Number 12,571) for the Navy was delivered 12 years later.

Vought's two most important production jobs today are the new fighter Cutlass, a twin-engined jet carrier plane of unique design, and the Regulus, a surface-to-surface guided missile. In May 1953, Chance Vought won a Navy day-fighter competition—an important future project for this division.

The first Sikorsky helicopter climbed somewhat unsteadily into the air at Stratford on September 14, 1939. At about 30 ft., Igor Sikorsky brought it to a stop. Gently he moved the sensitive controls, and the little machine backed, went sideways, came to a stop again, and then, completely under control, landed on the precise spot from which it had climbed a few minutes before. This little ship carried one person—the pilot.

Since then the helicopter has shown itself to be the most versatile instrument of transportation ever devised by man. Its uses are many and varied, but its outstanding contribution has been as an agent of mercy. On sea and on land, in the jungle and the Arctic, Sikorsky helicopters have meant the difference between life and death for thousands. More than 10,000 wounded, many from within the enemy lines, have been rescued by them in Korea.

In July, 1952, four officers of the Air Rescue Service flew two Sikorsky H-19's from Westover Field, Mass., by way of Labrador, Greenland, and Iceland to Prestwick, Scotland, the first spanning of the ocean by helicopter. These same ships, with other Sikorsky's, rescued hundreds during the disastrous 1953 floods in Holland and England.

Sikorsky engineers have adhered generally to the basic configuration of the first helicopter, the single horizontal rotor for lift, and the vertical articulating tail rotor for directional control. The H-19 carries ten persons, including a crew of two. Before the end of this year a new twin-engined Sikorsky, capable of carrying 30 or more persons, will make its appearance.

UNITED STATES AVIATION UNDERWRITERS, INC.

New York, N.Y.

In reviewing the achievements of the United States Aircraft Insurance Group (USAIG) with respect to the aviation industry as a whole, it is not a selected list of unusually large risks or oversized losses that is important but rather that a group of otherwise unrelated fire, marine, and casualty companies banded together under a patriotic desire to support this infant industry 25 years ago. Had it not been for insurance backing, no part of the industry could have developed into what it is today.

The close tie-in between the industry and insurance begins with the simple matter of borrowing money. Regardless of the kind of industry involved, banks will not grant a loan unless the borrower has insurance protection and the more hazardous the business, the more important insurance becomes. Aviation needed insurance but that was not necessarily true in reverse. It is to

Leading jet makers call on AMERICAN for special connectors*

to carry fuel, oil, hot and cold air, and as vent and drain lines

- expert technical staff at your service . . . helpful sales engineers in your area
- *The American Brass Company, American Metal Hose Branch, Waterbury 20, Conn. In Canada: The Canadian Fairbanks-Morse Co., Ltd.* 53220

WHEREVER CONNECTORS MUST MOVE **AMERICAN** flexible metal hose and tubing an ANACONDA® product

*ALSO—Ignition Shielding Conduit Assemblies, Shielding Conduit to Military Specifications, Flexible Metal Air Ducts, Exhaust Lines, Parachute Rip Cord Housings.

the permanent honor of these pioneering insurance companies, that they, with little or no profit in sight, played a large part in keeping the aircraft industry alive, prior to World War II, until such time as the formal declaration of war enabled the Government to take over and manufacture its own airplanes, thus defeating the central powers.

Noteworthy among the many important aviation milestones insured by the USAIG are the first flight conducted entirely blind for the Guggenheim Foundation by Jimmy Doolittle, the first nonstop coast-to-coast passenger flight in less than 12 hours; the first accident insurance for pilots in the armed services; the London to Melbourne race entry of the DC-3 flown by Roscoe Turner; the high-altitude balloon flights, sponsored by the National Geographic and carried out by Captain Stevens—each, in its own way, a forward step in the art of flying. Last but not least the USAIG was happy to have insured the test flights of such famous aircraft, among others, as the 314 Clipper, the B-19 and the B-24, and the DC-3 and the DC-7.

Safety in flying has always held the attention of USAIG executives, an interest that has cost them much time and money in promoting it. As an outstanding example of this interest, they have, for a number of years, retained Jerry Lederer, one of the prominent aeronautical safety engineers of the country, as a consultant. Additional phases of this strong safety campaign covered wider use of parachutes in the early days; the use of safety belts, especially on airlines; more extensive use of the Link Trainer; installation of the barograph on air-line equipment; and an extensive program aimed at the establishment of separate and distinct air-line safety engineering departments reporting directly to the top executive.

VICKERS INCORPORATED

Detroit, Mich.

From such simple beginnings as the raising and extension of landing gear, landing flap operation, nose-wheel power steering, and surface control power boost, hydraulics began to enter more complex fields. Vickers Incorporated has contributed heavily to this growth.

In recent years the control of guns has become fully automatic, and radar signals fed to Vickers electrohydraulic servo pumps automatically aim airborne armament. Hydraulics have their part in the flight-refueling program for the handling of the boom and the operation of the fuel-transfer pumps. Aircraft hydraulics have been used to vary the angle of incident for fighter wings, to extend and retract rocket magazines, to provide a rescue hoist for helicopters, for the opening and closing of cockpit enclosures, and for the control of afterburner orifices. There are many more interesting Vickers hydraulic applications in addition to these.

Vickers fixed displacement pumps and motors are available in 32 standard sizes. The smallest has a theoretical delivery in gallons per minute (at 1,500 r.p.m.) of 0.61; the largest pump delivers 23.8 gal. per min. at 1,500 r.p.m. The smallest pump (or motor) can operate intermittently at 9,100 r.p.m. delivering 6 hp., yet is small enough to be held in the palm of one's hand.

The basic Vickers variable displacement pump has been provided with many automatic features in recent months. It can be automatically pressure-compensated to deliver only the amount of oil required while maintaining a constant pressure. An electrical depressurize feature permits the pump to be selectively disconnected from the circuit to save even the nominal power required to rotate the unit at zero displacement. Across-center designs can deliver oil in either direction without changing the input shaft rotation. The pump can be positioned at dead center and this permits static positioning of the driven end. Inasmuch as the 3,000 lb. per sq.in. field has been successfully brought under control, higher pressures can now be anticipated.

Vickers Incorporated, whose main offices are located at Detroit, Mich., is the exceptional supplier of aircraft hydraulic accessories who can provide most of the components necessary to build a complete system.

In addition to pumps and motors, Vickers makes pressure relief valves, accumulators, unloading valves, and a variety of other special hydraulic units. An example is the pump control valve, which acts as a fire-wall cutoff, a bypass, an over-pressure relief, a thermal relief, and a manual cutout. Solely a supplier of hydraulic accessories, Vickers Incorporated is constantly introducing new and unusual devices for this industry.

WESTERN GEAR WORKS

Lynwood, Los Angeles County, Calif.

At the 50th Anniversary of Flight, Western Gear Works notes that since the beginning their share has been contributed to the development of larger, faster, safer, and more comfortable aircraft. Early wood and wire planes were equipped with Western Gear Works chain sprockets. The heat-treating facilities and know-how strengthened early tubular structure airplanes. Improved airplanes changed sprockets to gears, then gear boxes, followed by remote actuators, accessory drives, large landing-gear screws, specially shaped high-strength parts, and main propulsion gearing. Each year as aviation advanced, Western Gear Works has added production know-how to engineering and research, providing more safety and more reliability, along with lighter weight and higher quality, to the many Western Gear-designed aircraft parts. Research and continuous testing have developed know-how to produce better aircraft gears and equipment. Western Gear engineers design for the aviation industry in all its branches—the research wind tunnel, testing models, experimental and prototype aircraft, military and commercial aircraft, helicopters, guided missiles, gas turbines, radar, and rockets—providing specially designed aircraft equipment for the many applications requiring power transmission. Electric, hydraulic, pneumatic, and gas-turbine prime movers, combined with suitable gearing, are designed into compact packages to produce the desired final motion required by the flight vehicle to provide the control for flight of today's phenomenal aircraft.

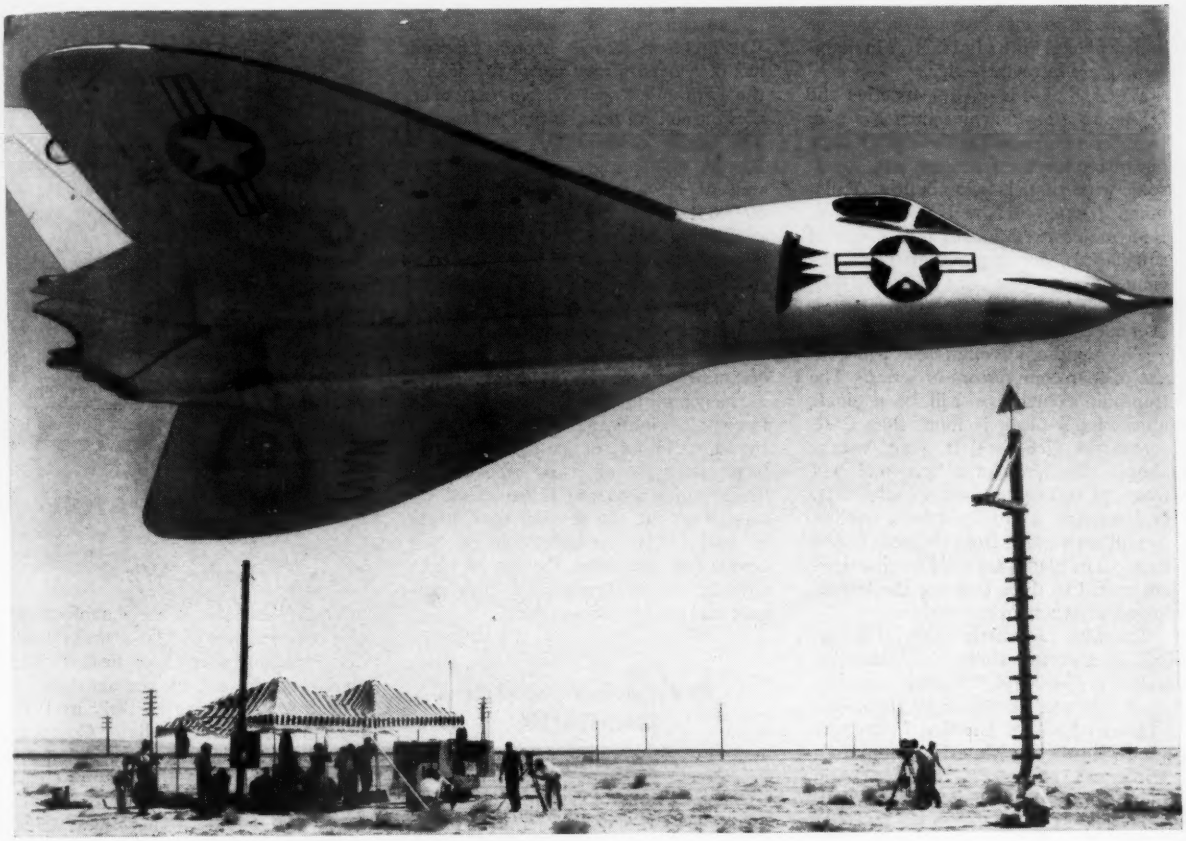
WESTINGHOUSE ELECTRIC CORPORATION

Pittsburgh, Pa.

The diversified activity of Westinghouse in the aircraft industry is illustrated by the following résumé of a few of the Company's noteworthy developments during the past year or two.

In September, 1952, the Navy and Westinghouse announced that Westinghouse had developed and placed in production the world's most powerful qualified turbojet aircraft engine, the J-40 with afterburner. The engine is of the axial-flow type, a Westinghouse design feature since the Company pioneered jet-engine development in this country more than 10 years ago.

The new power plant is the first jet engine in the world to provide constant-speed drive for airplane accessories as an integral part of the engine. This feature will permit designers to make



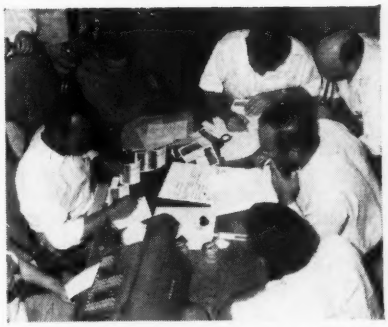
Westinghouse J40 powers F4D to world speed record

U. S. Navy establishes mark of 753.4 mph

A Westinghouse J40 turbojet powered the Douglas F4D "Skyray" to 761.414 mph as it recaptured the world speed record for the United States by streaking to an official average of 753.4 mph over the required course.

Designed and manufactured by the Westinghouse Aviation Gas Turbine Division in South Philadelphia, Pa., the J40 and other outstanding turbojets now are being produced at the huge Westinghouse jet engine plant in Kansas City, Mo.

This J40 contribution to record-breaking jet progress is another example of Westinghouse turbojet leadership. Westinghouse Electric Corporation, Aviation Gas Turbine Division, Lester Branch P. O., Philadelphia 13, Pa. J-54032-A



Official representatives check film of individual passes—746.075, 761.414, 746.053 and 759.499 mph—to determine official average of the Westinghouse powered Douglas F4D.

YOU CAN BE SURE...IF IT'S Westinghouse

substantial savings in weight and space in new planes, both vital factors in maintaining aircraft superiority.

Westinghouse is putting together the largest rotating machine man has ever built. It comprises the five compressors and drive for the transonic and supersonic wind tunnels being built at Tullahoma, Tenn., for the U.S. Air Force. Four motors with a combined power of 216,000 hp. are required to drive the compressors. Two of these—83,000-hp. synchronous motors—are the largest ever built.

The supersonic compressor will consist of four compressors in series. The transonic compressor will be a single unit. Each blade is more than 2 ft. across the face, is 6 ft. long, weighs almost two-thirds of a ton, and will rotate at 600 r.p.m. on a spindle 18 ft. in diameter. Centrifugal force tending to pull each blade from its roots is 800 tons. The blades are solid forgings and are rooted to discs that are the largest forged anywhere in the world.

The first automatic pilot with unlimited maneuverability has been installed in the F-94C "Starfire" jet warplane. It was developed by the Westinghouse Air-Arm Division in cooperation with the Air Material Command's Armament Laboratory. The automatic pilot utilizes three "nontumbling" gyroscopes that are locked to the plane.

These gyroscopes, each spinning at 12,000 r.p.m. follow the plane's movements during all maneuvers without any possibility of tumbling. They differ from the ordinary "position" gyro that is not locked to the plane and, hence, resists any effort to change its direction of motion. Whereas former gyros were sensitive only to changes in angle in the plane, the new autopilot equipped with "rate" gyros responds to the rate at which changes take place.

The aircraft department of the Westinghouse Small Motor Division has developed a new magnetic amplifier voltage regulator suitable for use with aircraft narrow-speed-range a.c. generators. The unit is completely static; contains no electron tubes, hot-wire tubes, or cold-cathode gaseous tubes of any type; and can be used as a direct replacement for carbon pile regulators now in service with conventional 400-cycle a.c. generators.

The aircraft department of the Westinghouse Small Motor Division has developed a new temperature control unit to regulate the application of power for deicing airplane windows. The sensitive electronic controls are hermetically sealed in inert gas. This entire unit is supported on shock-absorbing mounts and functions normally throughout a temperature range from −65° to +71°C. and does not change calibration when subjected to humidity or actual condensation of moisture.

The aircraft department of the Westinghouse Small Motor Division has developed a new motor for driving the hydraulic boost system that operates the control surfaces of a jet bomber. The motor delivers $3\frac{1}{2}$ hp. from a 30-volt, d.c. supply and commutates well at elevations from sea level to 50,000 ft.

Unusual for a motor of this size is the construction of the armature. The commutator is rib-mounted on a splined shaft, providing air passages under the commutator and into a unique winding. Also, a spiral groove is cut into the commutator, providing better cooling of the commutator and brushes through forced-air circulation and preventing the formation of hot spots on the brush face. Because of this groove, the brush spring pressure is decreased by enough to cut the friction (and heat) in half. The incorporation of this groove has permitted the use of high-altitude treated brushes for both altitude and sea-level operation.

WYMAN-GORDON COMPANY

Worcester, Mass.

Wyman-Gordon Company, producing forgings since 1883, has pioneered in the development and production of aircraft forgings from the early forged aircraft crankshaft to the latest titanium applications.

Also, as a leader in heavy press forging, Wyman-Gordon was selected to operate the Air Force 18,000-ton press plant, beginning in 1946. Currently, this facility is being expanded to house a 50,000-ton press and a 35,000-ton press, with production to begin in 1954.

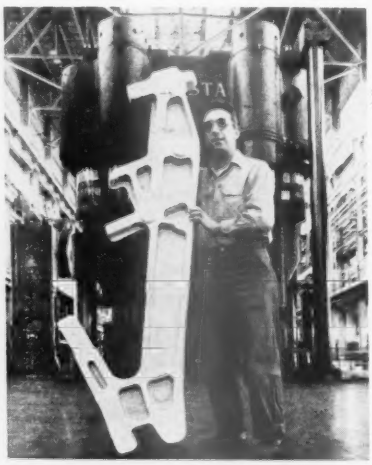


Photo of forging made on the 18,000-ton press operated by Wyman-Gordon Company for the Air Force at North Grafton, Mass.

YOUNG RADIATOR COMPANY

Racine, Wis.

Young Radiator is the manufacturer of a complete line of heat-transfer products including specialized heat-transfer equipment for use by the aeronautical industry. Beginning as early as 1913, personnel of Young Radiator Company have built equipment for aviation applications, the first unit being for Glenn L. Martin's endurance flight around the Great Lakes. Since that time Young has conducted a continuous research program in this field designed to give the latest in heat-transfer equipment. *Young Radiator Company:* General offices, Racine, Wis., U.S.A. Plants at Racine, Wis., and Mattoon, Ill.

When you write to manufacturers whose advertising appears in the

Aeronautical Engineering Review,

it will be of interest to the companies and of benefit to the Institute if you mention that you saw it in the

Aeronautical Engineering Review

The Ideal Gift for 1953

A Complete Record of U. S. Aviation Industry and Achievements since 1903

TYPICAL PRESS COMMENTS

"It is the best year-by-year chronology of American aviation history in print. The photo selection is excellent and the annual summaries of aviation firms, many of whom have long since vanished, makes fascinating study."

—Aviation Week

". . . a publishing feat unusual in several ways . . . Its 178 pages are filled with priceless pictures from Kitty Hawk to Muroc."

—New York Times

". . . (a book) to study and enjoy—and ponder."

—AP Newsfeatures

". . . It is one of the best books on the subject that has come to the attention of this corner in a long while."

—Los Angeles Examiner

". . . probably the most complete chronology of aviation ever published in the United States."

—Los Angeles Times

- ***Important facts about who did what—and when***
- ***600 illustrations of the various airplanes built***

Here is a gift that can be appreciated by your friends and your own youngsters for a lifetime. Order those extra copies now. The supply is limited.

INSTITUTE OF THE AERONAUTICAL SCIENCES
2 E. 64th Street, New York 21, N.Y.

Publications Dept.

Gentlemen:

Enclosed is $_____* for_____cop(y)ies of "Fifty Years of Flight." Please forward at once to:

Name_____

Address_____

DEPARTMENT OF TECHNOLOGY
BUFFALO PUBLIC LIBRARY

*** $5.00 per copy, postage prepaid (Less 10% Discount to IAS Members). Special discounts quoted on quantity orders.**

IAS Preprints

Preprints of Annual Summer Meeting Papers Currently Available

		Member Price	Nonmember Price
426	Wing-Body Interference at Subsonic and Supersonic Speeds: Survey and New Developments—H. R. Lawrence and A. H. Flax.	$0.35	$0.75
424	Design of the Hiller HJ-1, YH-32 Helicopter—H. Holm.	0.35	0.75
423	Afterburners—Are They Worth While?—F. C. Newton.	0.35	0.75
422	Fatigue Life of Thick-Skinned Tension Joints—Edward W. Thrall, Jr.	0.50	0.85
421	Spreading of Supersonic Jets in Supersonic Streams—John G. Wilder, Jr., and Kenneth Hindersinn.	0.65	1.00
420	Energy Approach to the General Aircraft Performance Problem—Edward S. Rutowski.	$0.50	$0.85
419	Optimum Design Considerations for Aircraft Wing Structures—Aaron L. Kolom.	0.50	0.85
418	Techniques for Determining Thrust in Flight for Airplanes Equipped with Afterburners—L. Stewart Rolls and C. Dewey Havill.	0.35	0.75
417	Optimum Exit Nozzle Performance for Jet Engines—Richard G. Laucher and John S. Winter.	0.35	0.75
416	Applications of Hypersonic Thin-Body Theory—Milton D. Van Dyke.	0.50	0.85

Other Preprints of Papers Currently Available

415	What Magnetic Amplifiers Can Do To Increase Aircraft Reliability—G. F. Schroeder.	$0.35	$0.75
413	Adaptability of Electronics to Aircraft Engine Control—Joel D. Peterson and Robert W. Curran.	0.35	0.75
412	A Simple Thrust Indicator for Propeller-Driven Airplanes—A. W. Vogeley and M. N. Gough.	0.35	0.75
411	Experimental Investigation of the Characteristics of the Supersonic Laminar and Turbulent Boundary Layer at M = 3.1—W. S. Bradfield, D. G. DeCoursin, and C. B. Blumer.	0.65	1.00
410	Effects of Articulated Rotor Dynamics of Helicopter Automatic Control System Requirements—Charles W. Ellis.	0.50	0.85
409	An Exact Solution for the Buckling Load of Flat Sandwich Panels with Loaded Edges Clamped—S. V. Nardo.	0.50	0.85
408	**(See Sherman M. Fairchild Fund Paper** No. FF-8.)		
407	The Structural Tail Load Problem—Theory, Tests, and Criteria—Richard Koegler.	0.35	0.75
406	The Creep Deflections of Beams and Columns—Yoh-Han Pao and Joseph Marin.	0.35	0.75
404	Studies of Some Effects of Airplane Configuration on the Response to Longitudinal Control in Landing Approaches—R. W. Stone, Jr., and W. Bihrle, Jr.	0.50	0.85
401	Military Air Cargo Carrier Trends—Walter Tydon.	$0.35	$0.75
400	Forward-Flight Lateral Stability and Flying Qualities Studies of the Tandem Helicopter—K. B. Amer.	0.35	0.75
398	Subsonic Compressibility Corrections for Propellers and Helicopter Rotors—E. V. Laitone and L. Talbot.	0.50	0.85
397	Supersonic Flow About Slender Bodies of Elliptic Cross-Section—A. Kahane and A. Solarski.	0.65	1.00
396	Some Aerodynamic Effects of Streamwise Gaps in Low-Aspect-Ratio Lifting Surfaces at Supersonic Speeds—Z. O. Bleviss and R. A. Struble.	0.65	1.00
394	Stress Analysis of Sheet Stringer Panels with Cutouts—H. G. McComb, Jr.	0.65	1.00
393	Notes on the Analysis and Design of Multi-Post Stiffened Wings—D. M. Badger.	0.65	1.00
388	The Effect of Propeller Control Parameters on Gas-Turbine Power Ratings and Flight Efficiency—R. C. Treseder, M. Brooks, and J. R. Kessler.	0.35	0.75
386	The Shock Ignition Engine—Frank F. Rand, Jr.	0.35	0.75
385	Effect of Creep on Column Deflections—T. P. Higgins, Jr.	0.50	0.85

Preprints should be ordered by number from:

Preprint Department, Institute of the Aeronautical Sciences

2 East 64th Street, New York 21, N.Y.

FOR YOUR

1954 Advertising Program

AERONAUTICAL ENGINEERING REVIEW

For your monthly advertising messages to the aircraft industry's engineering and design personnel—the men who influence buying.

AVIATION MARKET GUIDE Now Available!

24 pages of FACTS on your market and REVIEW.

Write for your free copy TODAY!

OFFICIAL PUBLICATION: INSTITUTE OF THE AERONAUTICAL SCIENCES, INC.

2 East 64th Street
New York, New York

BRAIN SURGEONS...

FOR GUIDED MISSILES

Guided missiles are, fundamentally, planes without pilots... officially referred to as "pilot-less" aircraft. But, *something* must take the place of the human element to make the missile work... to fulfill its mission.

The problem of developing that "something"...a replacement for the pilot...is a challenging assignment for highly trained scientists and engineers such as the "brain surgeons" of Bell Aircraft's large and diversified electronics and servomechanisms departments.

Complex electronics systems are the "brains" of a missile. Servomechanisms provide the "muscles." Development of successful "brain-muscle" systems is typical of the advances made by Bell Aircraft engineers for our armed forces.

Bell's electronics and servomechanisms programs also include design and production of various types of radar, proportional control equipment, telemetering systems, automatic landing devices and several different types of auto-pilots.

Thorough research, advanced engineering and sound production which distinguish Bell products will provide major contributions to transportation, commerce, industry...and the future defense of our nation.

BELL Aircraft CORPORATION

Buffalo, N. Y. Fort Worth, Texas

Engineers interested in career opportunities—write Engineering Personnel Dept., Buffalo.

News of Members

(*Continued from page 36*)

been with Cornell Laboratory since 1946.

▸ **Joseph Marin** (M), Professor of Engineering Mechanics and Research Professor of Engineering Materials, The Pennsylvania State College, was recently appointed Head of the Department of Engineering Mechanics, Pennsylvania State.

▸ **William A. Patterson** (M), President, United Air Lines, Inc., was elected on September 18 to serve as Chairman of the Business-Education Committee for Economic Development.

▸ **Captain P. V. H. Weems** (F) has announced that three organizations with which he is associated and which cover the broad field of navigation and navigation consultant services are now located as separate firms in the Werntz Building, 227–229 Prince George Street, Annapolis, Md. The three organizations are: Weems System of Navigation; Aeronautical Services, Inc.; and Weems and Plath, Inc.

Members on the Move

The purpose of this section is to provide information concerning the latest affiliations of IAS members. All members are therefore urged to notify the News Editor of changes as soon as they occur.

Niels C. Beck (M), Program Development Engineer, Armour Research Foundation, Illinois Institute of Technology. Formerly, Dean, Parks College of Aeronautical Technology, St. Louis University.

Walter Bodofsky (TM), Designer, The Glenn L. Martin Company. Formerly, Engineering Group Leader, Chase Aircraft Corporation, Willow Run, Mich.

Sergeant Miguel E. Bustamente, Jr., USMC (TM), VMR 352, MAG 25, MCAS, El Toro, Calif. Formerly, Corporal and Student Navigator, MCAS, Cherry Point, N.C.

Norman R. Cooper (TM), Aerodynamicist, North American Aviation, Inc. Formerly, Research Engineer, Defense Research Laboratory, University of Texas.

Seymour J. Deitchman (M), Research Aeronautical Engineer, Weapons Branch, Development Division, Cornell Aeronautical Laboratory, Inc. Formerly, Aerodynamicist, Bell Aircraft Corporation.

Donald J. Dike (TM), Assistant in Research, Forrestal Research Center, Princeton University. Formerly, Junior Aerodynamics Engineer, Consolidated Vultee Aircraft Corporation.

Anthony W. Fiore (TM), Aerodynamic Research Engineer, Wind Tunnel Branch, Wright Air Development Center, Wright-Patterson AFB, Ohio. Formerly, Project Engineer and Aerodynamicist in Charge—

Sidney H. Webster, MIAS, has been appointed Manager of the Northeastern District, Jack & Heintz, Inc., with headquarters at 11 W. 42nd St., New York. Mr. Webster, who holds a B.M.E. degree from Northeastern University and studied aeronautical engineering at Massachusetts Institute of Technology, was formerly Assistant to the President, Aviation Engineering Division, Avien-Knickerbocker, Inc.

Transonic Wind Tunnel Research, WADC, Wright-Patterson AFB, Ohio.

David Newton Foner (TM), Supervisor, Vibration and Mechanical Metallurgy, Hamilton Standard Division, United Aircraft Corporation. Formerly, Senior Analytical Engineer, Hamilton Standard.

Professor Victor M. Ganzer (AF), Executive Officer, Department of Aeronautical Engineering, University of Washington. Formerly, Acting Executive Officer, Department of Aeronautical Engineering, University of Washington.

Seymour Gottlieb (M), Staff Attorney, Helicopter Division, Bell Aircraft Corporation. Formerly, Supervisor of Military Contracts, Helicopter Division, Bell.

Loral D. Bonham, MIAS, was recently appointed Chief Engineer, Fletcher Aviation Corporation. Mr. Bonham, who was graduated from the University of Cincinnati in 1933, had formerly been Assistant Chief Engineer with Fletcher for the past 6 years.

William C. Holmes, Jr. (M), Chief, Power Plant Engineering Department, Northrop Aircraft, Inc. Formerly, Assistant to Assistant Chief Engineer, Project and Components, Northrop Aircraft.

Miss Rosalyn E. Hyde (M), Test and Development Engineer, Structural Design Department, Missile Branch, Chrysler Corporation. Formerly, Stress Analyst, New York Engineering Office, Republic Aviation Corporation.

Captain John Warburton King, USN (Ret.) (AF), Assistant to the President, Stroukoff Aircraft Corporation. Formerly, Chief of Staff, Naval Air Material Center, Philadelphia, Pa.

Arthur S. Lundgren (M), Design Engineer, Douglas Aircraft Company, Inc. Formerly, Structural Designer "A," Douglas Aircraft Company, Inc.

Maitland McLarin (TM), Supervisory Electronic Engineer GS-11, Engineering Group #2, Electronic Test, Naval Air Navigation Electronics Project, USNAS, Patuxent River, Md. Formerly, Assistant Product Engineer, Aeronautical Bombardment Engineering Department, Sperry Gyroscope Company, Division of The Sperry Corporation.

George E. Merer (M), Engineering Staff Member, Melpar, Inc., Research Laboratory of Westinghouse Air Brake Corporation. Formerly, Electronic Scientist, Rome Air Development Center, Griffis AFB, N.Y.

Captain William J. Morrow (M), now Office of the Air Attaché, U.S. Embassy, Paris, France; A.P.O. 230, c/o Postmaster, New York.

H. Erich Nietsch (M), Manager, Industrial Division, Robinson Aviation, Inc. Formerly, Assistant to the President, Robinson Aviation.

J. H. Overholser (M), Assistant to the General Manager, Pacific Division, Bendix Aviation Corporation. Formerly, Executive Vice-President, Hydro-Aire, Inc.

William H. Pratt (TM), Flight Test Engineering, Fort Worth Division, Consolidated Vultee Aircraft Corporation Formerly, Project Engineer, Marine Aircraft Corporation.

E. W. Saboya de Albuquerque (TM), Chief of Aerodynamics, Helicopter Design Bureau, Air Materiel Division, Ministry of Aeronautics, Rio de Janeiro, Brazil. Formerly, Aeronautical Engineer, Helicopter Design Bureau, Ministry of Aeronautics, Brazil.

Richard G. Summers (TM), Senior Development Engineer, Chance Vought Aircraft Division, United Aircraft Corporation. Formerly, Graduate Student, Graduate School of Aeronautical Engineering, Cornell University.

R. B. Tamboli (TM), Aerodynamicist, The de Havilland Aircraft Company, Limited, England. Formerly, Aerodynamicist, The de Havilland Aircraft of Canada, Ltd., Canada.

Warren P. Turner (AM), Manager, Customer Relations Division, Reaction Motors, Inc. Formerly, Manager, Customer Relations, Reaction Motors, Inc.

ANOTHER REASON ALLISON LEADS IN THE AIR

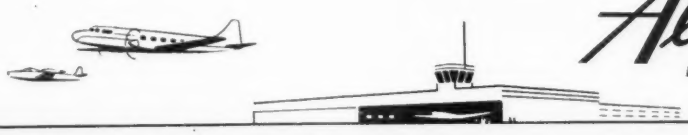
9 to 1, his jet trainer is powered by Allison

NEXT time you see a jet plane streaking across the sky, it's 9 to 1 the pilot was trained in an Allison-powered jet trainer. Because 9 out of every 10 Air Force and Navy jet pilots earn their wings in jet trainers powered by Allison J33 Turbo-Jets.

There's a good reason for this—the J33 was the first jet engine to be built in production quantities in this country. Today, these J33's power nine Navy and Air Force planes, including the Air Force T-33 and Navy TV-2 trainers. Through Allison engineering, these engines have established records for dependability and long-time operations as proved by an Air Force technical order permitting 1200 hours' operation between major overhauls.

This vast background of experience in both design and manufacture of turbine engines is the reason our Armed Services rely on Allison engines to train the Free World's jet pilots.

GM GENERAL MOTORS



Allison

DIVISION OF GENERAL MOTORS
INDIANAPOLIS, INDIANA

World's most experienced designer and builder of aircraft turbine engines—*J35 and J71 Axial, J33 Centrifugal Turbo-Jet engines, T38 and T40 Turbo-Prop engines.*

Corporate Member News

• **Air Associates, Inc.** . . . Aviation Supply Corporation, of Atlanta, Ga., recently purchased by Air Associates, has been established as the Atlanta Branch. This Atlanta Branch of Air Associates will distribute the company's products to air lines, aircraft manufacturers, and airport service operators in Georgia, Alabama, Mississippi, Tennessee, South Carolina, and North Carolina.

• **AiResearch Manufacturing Company, Division of The Garrett Corporation** . . . The development of two new models of lightweight gas-turbine auxiliary power units was recently announced. One of these new AiResearch units is a compressed-air supply unit with a weight of 170 lbs. and an output rating of roughly the equivalent of 170 hp. The other is a combination compressor and shaft power unit from which both types of power can be extracted simultaneously; it is in the 120-hp. class. Two features of the new gas turbines are (1) the complete enclosure of the hot parts of the turbine and nozzle box in a pressurized chamber and (2) "the use of a single combustion chamber which eliminates dual ignition and any need for cross-firing means or fuel flow equalizers."

• **Aluminum Company of America** . . . The new Alcoa Building, located in the heart of Pittsburgh's Golden Triangle, was dedicated on September 15. This 410-ft. 30-story structure is America's first aluminum skyscraper, the construction of which was begun in May, 1950. The exterior walls of this office building are sheathed with hundreds of 6- by 12-ft. aluminum panels. In addition, aluminum was also used in the building's ceilings, stairs, wiring, piping, air conditioning, windows, lighting fixtures, door frames, and hardware.

• **American Airlines, Inc.** . . . According to a recent release by American, the airline industry's experiment in using local time for all of its schedules during Daylight Saving Time this past summer was an unqualified success. A survey conducted by American to determine passenger reaction to this new method of publishing schedules found 1,711 of those questioned in favor of it and 102 against it. (In this type of timetable, all arrivals and departures are published in the particular time being used in each locality, be it Standard or Daylight Saving.) . . . A pictorial story of the first 50 years of flight is being distributed by American. American, according to this 32-page booklet, was the first to introduce the Douglas DC-3 and the first to use the Douglas DC-7. The publication is entitled *Flight*.

The five helicopters shown in this montage demonstrate the progression of Bell Aircraft Corporation's manufacture of helicopters since the firm entered the rotary-wing field in 1942. *From top to bottom,* they are: Model 30, the first production model; Model 47B, an early version of the present utility series; Model YHB-12, an eight- to ten-place single-rotor transport type; Model 47G, the present production helicopter for military and commercial use; and the HSL, an antisubmarine tandem-rotor helicopter built for the U.S. Navy.

• **Beech Aircraft Corporation** . . . The first production model of the USAF T-34A Mentor was accepted about October 1 by USAF representatives. The T-34A, which is scheduled to become a standard USAF primary trainer, is powered by a 225-hp. Continental engine. It has a top speed of 189 m.p.h. and a cruising speed of 173 m.p.h. . . . A Manufacturing Control Department has been established at Beech.

• **Boeing Airplane Company** . . . An undisclosed number of B-47 Stratojet bombers are being returned to Boeing's Wichita Division after completion of assigned periods of USAF service. There they will undergo a thorough overhauling. Work will begin next June and will extend over an 18-month period.

• **Booz, Allen & Hamilton** . . . The USAF announced recently that a contract has been given to this firm for the purpose of making separate surveys at Republic Aviation Corporation and Northrop Aircraft, Inc. These surveys are to cover engineering, development, manufacturing, design, efficiency, etc.

• **Consolidated Vultee Aircraft Corporation** . . . According to a recent announcement, the USAF has ordered twin-engined turboprop military transport planes from Convair. The two transports, it is said, will be Model 340 Convair-Liners equipped with General Motors YT-56 Allison gas-turbine engines turning Aeroproducts propellers.

• **Cornell Aeronautical Laboratory** . . . A policy was recently established at Cornell Laboratory whereby qualified staff members would be given sabbatical leave. The first recipient of a sabbatical leave was Joseph G. Logan, MIAS, who is currently studying for his Doctorate in Physics at the University of Buffalo. . . . Eight graduate fellowships for study at Cornell University during the 1953–1954 academic year are being supported again by Cornell Laboratory. Two of these fellowships are sponsored in the name of Cornell Laboratory. The other six are supported in the name of six of the seven eastern aircraft companies that provided a working capital fund in 1946 for the Laboratory's early operation. These six companies are: Bell Aircraft Corporation, Republic Aviation Corporation, Curtiss-Wright Corporation, Avco Manufacturing Corporation, Fairchild Engine and Airplane Corporation, and Grumman Aircraft Engineering Corporation.

• **Douglas Aircraft Company, Inc.** . . . On October 3, a Douglas-Navy F4D Skyray, piloted by Lt. Comdr. James B. Verdin, USN, brought the world's speed record for the 3-km. straightaway dash back to

America's first twin-engined tandem transport helicopter, the YH-16 Transporter, was unveiled by the USAF on September 12. It was designed and built by Piasecki Helicopter Corporation under the auspices of the USAF Air Research and Development Command. The Transporter, which has a gross weight in excess of 15 tons, is capable of carrying 40 troops, 32 litter patients, or three jeeps. The helicopter has an overall length of 134 ft. and an overall height of 25 ft. Two versions are being built by Piasecki. The first one is powered by two Pratt & Whitney R-2180 reciprocating engines with take-off power ratings of 1,650 hp. each. The second version, the YH-16A, now under construction at the Piasecki plant, will have two Allison T-38 type shaft turbines. Air-line versions of the YH-16 are being planned and, according to the type of service, could seat from 48 to 72 persons.

this country by flying over the Salton Sea, Calif., area at an average speed of 753.4 m.p.h. This record-setting F4D is powered by a Westinghouse J-40 turbojet engine with afterburner. The F4D is the first airplane designed for carrier operation to hold a world's speed record. (This record had been held by Great Britain since September 7 when a Hawker Hunter was flown at 727.6 m.p.h. This record was broken on September 25 by another British aircraft, a Vickers Supermarine Swift, which averaged 737.3 m.p.h.). . . . On August 21, a Douglas D558-II Skyrocket was flown by Lt. Col. Marion E. Carl, USMC, to a new unofficial world's altitude record of 83,235 ft. Colonel Carl, who was the recipient of the IAS Octave Chanute Award for 1951, achieved a speed of 1,143 m.p.h., a new speed record for a military pilot. On August 15, 1951, Douglas Test Pilot Bill Bridgeman flew a D-558-II to 79,494-ft. altitude and a speed of 1,238 m.p.h. . . . At the time this issue went to press, it was expected that the American public would get its first look at the Douglas DC-7 about the latter part of November when this transport goes into nonstop coast-to-coast service for American Airlines, Inc. It was announced by American that the DC-7 is the first skyliner in history to fly scheduled trips nonstop from Los Angeles to New York. Other air lines that are awaiting delivery on the DC-7 are United Air Lines, Inc., Delta-C & S Air Lines, National Airlines, Inc., and Pan American-Grace Airways, Inc. . . . A total of $75,000 has been allocated by Douglas for educational scholarships for the 1953–1954 school year. Benefiting from the company's scholarship plan are some 700 Douglas employes and their children plus 19 colleges and universities throughout the country. . . . James Simpson, Vice-President of Douglas and General Manager of the company's Long Beach Division, died of a heart attack on September 16. Mr. Simpson had been with Douglas since 1922.

• **General Electric Company . . .** A rocket propulsion motor, capable of producing in excess of 20,000 lbs. of thrust, has been developed. It has been so designed that it can be "bundled" to meet a wide range of thrust requirements. Among some of the suggested uses to which this motor might be put are aircraft and torpedo propulsion, glider take-offs and landings, aircraft braking, catapult energizers, rocket boosters, and landing-craft boosters. . . . According to recently announced plans, the construction of a $1,800,000 combustion laboratory will get under way early in 1954. This structure, which will be an addition to the company's Research Laboratory at the Knolls near Schenectady, N.Y., will be used to aid scientists in obtaining knowledge needed to produce more powerful gas turbines for aircraft and other applications. The laboratory will be $1\frac{1}{2}$ stories and will provide 14,200 sq.ft. of floor space. Scheduled completion date is late 1954. . . . A small 8-oz. d.c. motor, measuring 1.625 in. in diameter and 2.375 in. in length, is now being produced by G-E's Specialty Motor Sub-Department. This motor is rated at 0.002 hp. at 6,500 r.p.m. and reportedly can be controlled by the output of two small vacuum tubes. Of the split-shunt reversible-rotation type, drawing maximum armature currents of 0.8 amp. from a 28-volt line, the "Tom Thumb drive" is required to withstand a high potential of 1,500 volts above the ground. It is said to be capable of responding to field currents of 0.00075 amp. It was designed to operate at either sea level or at 50,000 ft. and in temperatures as low as −65°F. . . . The ten thousandth jet engine was recently delivered to the USAF by G-E's J-47 jet-engine plant at Evendale, Ohio. This number, it was said, includes only the production at Evendale. . . . Two new bulletins, one on the new tank-mounted afterburner fuel pump for aircraft and the other on the new aircraft gas-turbine starter, are now available. Bulletin *GEA-5871A* covers the tank-mounted fuel pump; bulletin *GEA-5872A* explains the gas-turbine starter. . . . A 20-page booklet entitled *1953–1954 G-E Aircraft Components* (*GEA-5972*) is now available through the company's Electric Apparatus Sales Division. This illustrated booklet describes the 1953–1954 line of aircraft components, ranging from subminiature metal-clad capacitors for use in aircraft electronic equipment to air-turbine drives used in the operation of generators, hydraulic pumps, and fuel pumps.

• **Industrial Sound Control, Inc. . . .** A 3.5-lb. muffler, 5 in. square and 10 in. long, has been developed by Industrial Sound Control to whip the whine of the jet cockpit air-conditioning system. This high-velocity air-line muffler fits easily into the air-conditioning system of any existing aircraft, the company reports. Constructed of steel-lined aluminum, it is said to combine effective noise reduction with minimum pressure drop and to operate at temperatures of 500°F. and above. Extensive tests conducted indicate that the muffler provides a 50-db. high-band attenuation and an overall noise reduction up to 23 db.

• **Jack & Heintz, Inc. . . .** A newly developed method for detecting ground faults in aircraft or industrial d.c. electrical systems has been announced. It is an indirect-couple method that uses current transformers and which, according to the company, offers distinct advantages over the presently used shunt method. The advantages listed for Jack & Heintz's new method, as compared with the shunt-type circuit, are (1) reduced power demand, (2) reduced voltage drop, (3) sensing lead resistance not critical, (4) better maintenance, and (5) reduced size and weight. The transformer used in this indirect-couple method (Jack & Heintz—GC 66) is a special design featuring an air gap of 0.075 in. and is said to exhibit a linear response characteristic throughout the load range.

• **Kollsman Instrument Corporation . . .** The Kollsman C-2 True Airspeed Computer, believed to be the first of its type in the field, recently went into production. This unit is designed to act as a central data source on high-performance aircraft, furnishing multiple outputs of atmosphere pressure, Mach Number, and true air speed. This information, it is said, may be directed to control navigation, bombing, gun-fire control, and photographic equipment, as well as to provide visual indication for the flight crew. This unit, which is undergoing Qualification Approval Tests by the USAF, is basically a combination of a differential pressure pickup and a static pressure pickup with an electro-

Call in Parker for faster service on engine accessories for hot-air systems

"When you call in Parker for engine accessories, we can offer fast service on everything from proposals to shipments," explains R. P. McDonald, Parker sales engineer. He continues . . .

"Let me briefly describe these accessories for engine *hot-air* systems, from left to right. Our shutoff valve and pilot valve, used in nozzle cooling, are both extremely simple in design. The butterfly valve can operate at 500°F ambient and handle air up to 700°F.

"Shown on the right-hand page, our anti-icing and de-icing valves help keep an engine's air-intake section free from ice. Each can handle air up to 600°F. With seal modification, the de-icing valve will carry air up to 900°F. The motor-actuated shutoff valve assembly, shown on the far right, is available with rotor, butterfly, shear-plate, or poppet construction.

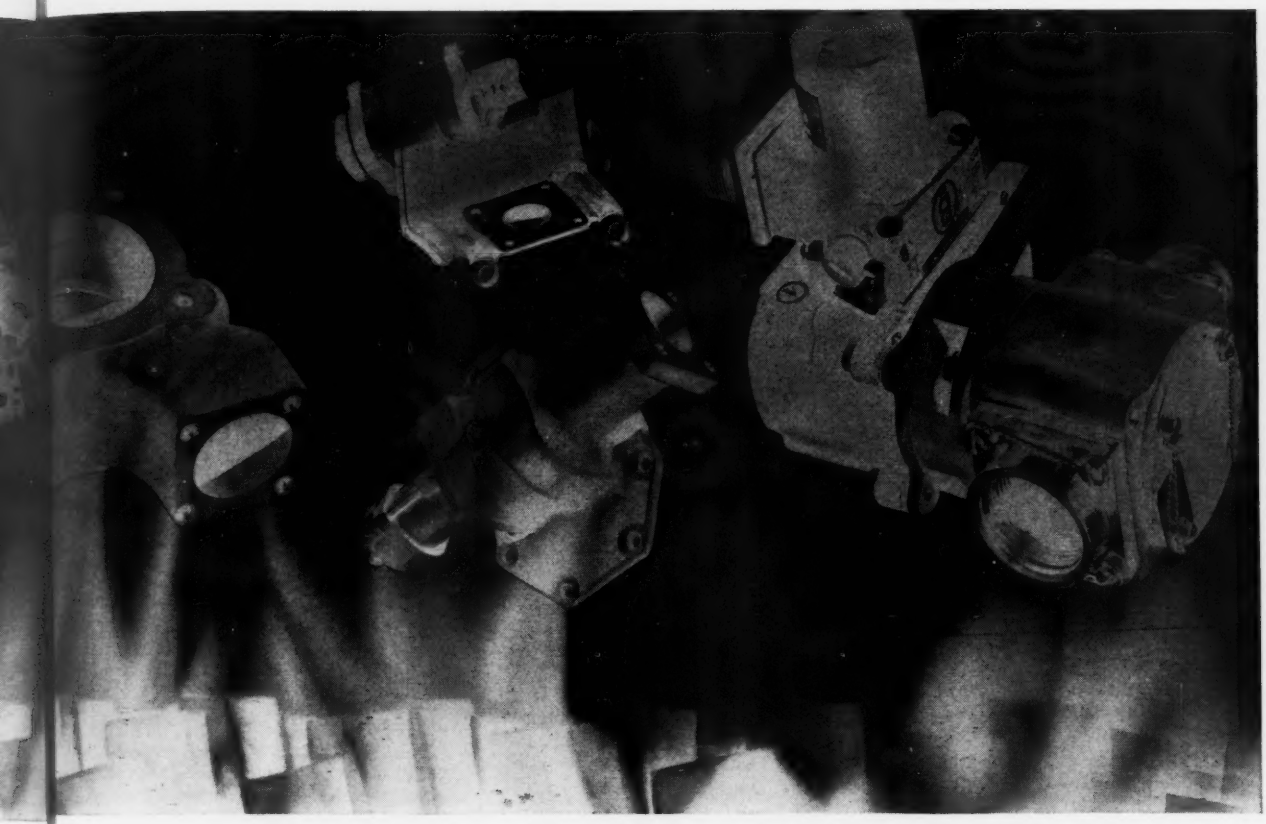
"Parker has centralized all engine-accessory engineering and manufacturing into a single operating division. Here you'll find engineers working to design accessories that offer not only extra performance benefits but also cost savings. Because quality depends largely upon precision manufacturing, you'll also find we use the most advanced manufacturing techniques and many one-of-a-kind machines. And, the inspections and tests that each accessory must pass prove Parker customers get what they order.

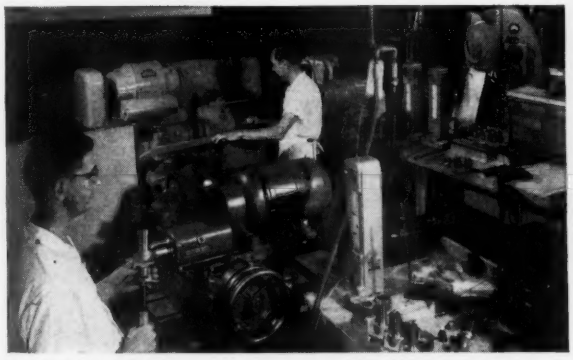
"Having a specialized group of customers, we are able to gear these facilities to a faster, more streamlined way of doing business.

"Whether you are interested in engine accessories for *hot-air* systems or for *fuel* or *hydraulic* systems, why not call us in? We'll be glad to discuss your requirements and offer assistance."

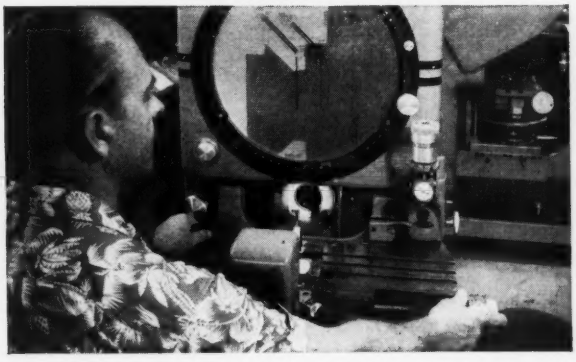
ENGINE ACCESSORIES DIVISION
The Parker Appliance Company
17325 Euclid Avenue, Cleveland 12, Ohio

Parker
Hydraulic and fluid system components

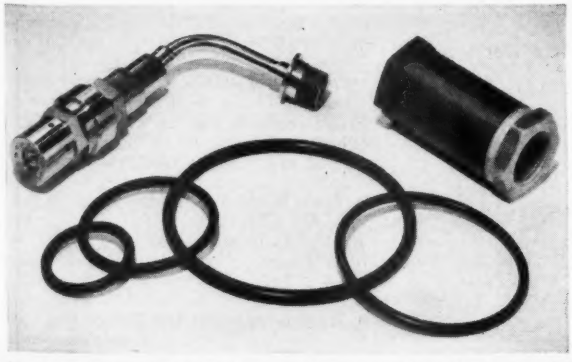




Precision grinding (shown above) on these stainless steel parts is checked to within 0.0001-inch accuracy. Grinders are able to hold 0.0002-inch concentricity between diameters.

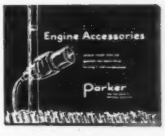


Inspections prove quality. Every accessory is 100% tested and inspected. Here's an optical comparator in use. We maintain close customer liaison to correlate test methods and results.



Look at these other Parker products: nozzle and check valve represent accessories for engine *fuel* and *hydraulic* systems. Also, Parker O-rings are approved for *all* military applications.

THE PARKER APPLIANCE COMPANY
Section 301-A
17325 Euclid Avenue
Cleveland 12, Ohio



☐ Please send me your new 24-page booklet about all types of Parker engine accessories, Bulletin 133081.

☐ O-ring catalog No. 5100.

NAME_____ TITLE_____

COMPANY_____

ADDRESS_____

CITY_____ STATE_____

DEPARTMENT OF TECHNOLOGY
BUFFALO PUBLIC LIBRARY

Send for new brochure. It's a 24-page picture tour of Parker's Engine Accessories Division, showing its products, plus unusual engineering, manufacturing and test equipment.

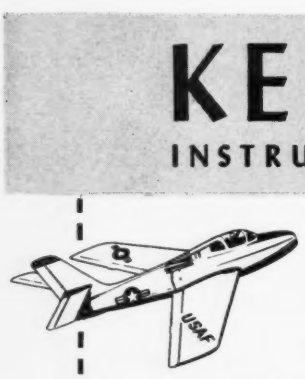
mechanical computer mechanism hermetically sealed into a cylindrical container. The computer mechanism includes three servos operating from individually sealed subminiaturized amplifiers. A flush resistance-type temperature bulb measures air temperature.

• **Lear, Incorporated . . .** Series 181 Rotary Actuator is now available from Lear. This unit is said to provide rotary output up to 15 watts at speeds ranging from 16 to 195 r.p.m. The maximum permissible torque is 25 lb. in. . . . A 28-page booklet entitled *This Is Lear* has been put out by the company. This publication covers the various activities of Lear and presents "the many interesting and unusual aspects" of the company.

• **Lockheed Aircraft Corporation . . .** It was recently revealed that Lockheed is conducting a preliminary design study on nuclear-powered aircraft under a USAF contract. No details as to the scope of this project were given. . . . Prototypes of the XF-104, a piloted jet fighter, are now being constructed.

• **North American Aviation, Inc. . . .** Vice-Presidents Raymond H. Rice and James S. Smithson were recently elected to North American's Board of Directors, bringing the membership of this body to twelve. Messrs. Rice and Smithson were elected in 1942 to their present positions, respectively, as Vice-President—Engineering and Chief Engineer and as Vice-President—Manufacturing.

KENYON
INSTRUMENT CO., INC.



Subcontractors to the AIRCRAFT INDUSTRY

Mechanical, hydraulic, pneumatic and fuel system devices built to prime contractor's drawings.

Close tolerance components and precise equipment designed and manufactured to prime contractor's specifications.

PHOTO EQUIPMENT for

Automatic Rapid Processing of Photographic Images for Ground and Airborne Installation.

Automatic Rapid Processing Radar Recording Cameras.

Automatic Rapid Processing X-Ray Cameras.

KENYON
INSTRUMENT CO., INC.
1345 NEW YORK AVENUE, HUNTINGTON STATION, L. I., N. Y.

• **Northrop Aircraft, Inc. . . .** On September 7, an F-89 Scorpion made a nonstop flight without refueling from Edwards AFB, Calif., to Dayton, Ohio, a distance of approximately 1,900 miles. The elapsed time was given as 3 hours and 45 min. The flight was made under search-and-interception speed conditions. . . . Following a recent action whereby Northrop's Board of Directors was increased from nine to ten members, William B. Collins, of New York, was elected a Director of the firm.

• **Pesco Products Division, Borg-Warner Corporation . . .** Paul W. Brannon, formerly Manager of Manufacturing, was recently elected Vice-President of Manufacturing. Mr. Brannon has been associated with Pesco Products since November, 1952.

• **Shell Oil Company and Eastern Air Lines, Inc. . . .** Under the terms of a recently executed contract, Shell will deliver an estimated $35,000,000 worth of aviation gasoline. Deliveries will begin February 1, 1954, to such points as LaGuardia Airport, New York; Washington, D.C.; Charlotte, N.C.; Atlanta, Ga.; New Orleans, La.; Houston, Tex.; St. Louis, Mo.; Louisville, Ky.; and Indianapolis, Ind.

• **Thompson Products, Inc. . . .** Through its recent purchase of Bell Sound Systems, Thompson Products has entered the commercial electronics field. In a recent announcement, it was stated that Bell Sound Systems, a Columbus, Ohio, manufacturer of high-fidelity amplifiers and tape recorders, would retain its identity and would continue its operation in Columbus as a wholly owned subsidiary of Thompson Products. The new Thompson subsidiary is under the overall direction of William M. Jones, Manager of Thompson's Electronic Division. Thompson executives serving on Bell's Board of Directors include Vice-Presidents H. A. Shepard and L. W. Reeves; Secretary and Senior Counsel Eben H. Jones, and William M. Jones. Judson S. Sayre, Thompson Merchandising Consultant, is also a member of the Board and acts as an Adviser on Bell's sales problems. . . . In mid-September, Thompson Products agreed to aid in the financing of The Ramo-Wooldridge Corporation, a new West Coast company devoted to research, development, and manufacturing in the general field of advanced electronics and guided missiles.

• **Tinnerman Products, Inc. . . .** A. H. Tinnerman, who has been President of the corporation since 1939, was recently made Chairman of the Board, while George J. Schad replaced him as President. Mr. Schad was elected to his former position as Vice-President in April, 1952.

• **Trans World Airlines, Inc. . . .** A 24-page brochure, *The Finest Air Fleet in the World,* has been put out by T.W.A. In it is described T.W.A.'s growth since 1930.

• **Westinghouse Electric Corporation . . .** Vice-President Leslie E. Lynde has been placed in charge of the Aviation Gas Turbine Division.

IAS Sections

Atlanta Section

Edith Hall Lively, *Secretary*

The first fall meeting of the Atlanta Section was held on September 10 in the Georgia Tech Dining Hall. George Baughman, Chairman for the previous year, opened the meeting by presenting the new slate of officers for the 1953–1954 session. These officers are as follows: Chairman, Prof. George K. Williams; Vice-Chairman, Prof. John J. Harper; Secretary, Edith Hall Lively; and Treasurer, Dr. Arnold E. Ducoffe.

In the absence of Chairman Williams, the meeting was turned over to Vice-Chairman Harper.

Mr. Baughman distributed questionnaires on proposed graduate-level aeronautical courses to be offered by Georgia Institute of Technology, either as a Saturday Seminar or as a night class during the week.

Vice-Chairman Harper introduced the speaker of the occasion, Carl E. Bricker, who is a graduate of the University of Akron in Mechanical Engineering. Mr. Bricker's field is concerned with the problems of airplane wheels and brakes. Since 1944 he has been in charge of the project engineering functions of Goodyear Aircraft Corporation's Wheel and Brake Development Department.

Mr. Bricker gave a highly technical talk on the design trend in wheels and brakes and on the dynamic stresses in wheel and brake design. His talk was illustrated with slides.

A sound movie, *Highlights of Farnborough—1952*, and a spirited discussion period completed the formal program.

Hampton Roads Section

John E. Duberg
Recording Secretary

The first meeting of the year of the Hampton Roads Section was held on September 9 at the Activities Building of the NACA at Langley Field; also participating was the local chapter of the American Society of Mechanical Engineers. More than 100 members and guests were present. The meeting was opened by the new Chairman for the year 1953–1954, H. H. Jackson, who introduced the new officers to the Section.

The speaker for the meeting, A. M. Rothrock, Assistant Director of Research of the NACA, was introduced by Dr. H. J. E. Reid, Director of the Langley Laboratory. Mr. Rothrock is well known at the Langley Laboratory where he carried out his early research work on fuels and lubricants in the years 1926 to 1942. In 1942, he became associated with the Lewis Flight Propulsion Laboratory and the following year was made its Director of Research. In 1947, he was transferred to his present position in the Washington Headquarters of the NACA in which position he is responsible for research in aircraft propulsion. Mr. Rothrock has had an excellent background in the field of the aircraft turbojet engine, the subject of his talk.

The speaker introduced his subject by discussing briefly the fields of application of the reciprocating engine, the turboprop, the turbojet, and the ramjet in aircraft propulsion. He showed that, at speeds greater than that of sound, the turbojet is a reasonably efficient prime mover but that the greater drag of the aircraft at these speeds resulted in speed ranges lower than those obtainable at subsonic speeds. He presented curves that showed the effects of the main turbine engine and flight variables (i.e., compressor-compression ratio, turbine inlet temperature, aircraft speed, and altitude) on the specific output and specific fuel consumption of the engine. He emphasized the interrelation of the effects of compressor pressure ratio, turbine inlet temperature, and flight speed; translated these factors into thrust and specific engine weight at altitude; and showed the manner in which the overall performance of the engine is estimated. He also showed how flight speed and altitude are related to engine stresses and are therefore a factor in determining engine weight.

From this general background of the factors influencing turbojet engine performance, Mr. Rothrock turned to the major research and development problems that face those who are trying to increase engine performance. The experimental attack on these problems is complicated by the fact that most turbojet engine operation is done at high speeds and high altitudes. It is therefore necessary to have available such high-altitude test facilities as exist at the NACA Lewis Flight Propulsion Laboratory and are under construction for the Air Force at Tullahoma, Tenn., and for the Navy at Trenton, N.J. One of the means of increasing engine performance is the development of compressors with greater air handling ability and with fewer blades. Major increases in engine performance can be obtained by higher operating temperatures, but this necessitates engine cooling. Mr. Rothrock discussed the research effort in this direction. In discussing the process of combustion, the speaker showed the relationship between altitude and combustion blowout and the effect on flame speed of the molecular structure of the fuel components.

Meet Your Section Chairman

Erratum

In the October issue of the AERONAUTICAL ENGINEERING REVIEW Alfred F. Stott's affiliation was carried as The Aeronautics Academy, Inc. It should have read the Aeronautical University, Inc.

Montreal Section

Gordon Rosenthal, *Secretary*

The first meeting of the 1953–1954 season was held on October 5 in the Main Dining Room of the International Aviation Building. Chairman A. E. Ades presided.

The speaker of the evening, Dr. Hubert Quinn, Manager of Research and Development, Canadian Aviation Electronics Ltd., was introduced by Vice-Chairman R. H. Guthrie. Dr. Quinn spoke on "Flight Simulators" and exhibited some of the components of a typical flight simulator, including normal aircraft instruments modified to operate by electrical drives rather than by pressures, accelerations, and other means. A working servomechanism demonstrating rate control was also shown.

The speaker outlined the electrical methods for representing the aircraft and control motions involved in a simulator and the part played by servomechanisms. A description of the composition of a simulator unit, the crew department, the monitoring console, and the "trouble panel" was given in detail.

The main purpose of a simulator is to provide flight crews with experience in coping with a wide variety of emergencies in a particular aircraft type. The crews can be subjected to simulated power-plant failures, instrument or auxiliary systems failures, icing of the air frame or engine, and, in the case of military aircraft, enemy damage.

An attempt is made in designing such a unit to reproduce the environment of the aircraft, including its sounds and even its vibrations. The steps involved in designing and developing a simulator from the basic information were traced.

Considerable interest in the talk was displayed by the audience during the

AVICA
FEATHERWEIGHT
STAINLESS STEEL
TUBE
ASSEMBLIES
for
SYNTHETIC
OIL LINES

● MECHANICALLY ATTACHED ALUMINUM FITTINGS
● SAVE WEIGHT

The AVICA combination of aluminum fittings with stainless steel flexible tubing, resistant to all synthetic oils used in aircraft systems, offers a large weight reduction over an all stainless steel unit, without performance loss.

NO WELDING OR BRAZING
used in end fitting attachment.

SAVE WEIGHT and INCREASE PERFORMANCE on synthetic oil lines.

We develop tube assemblies to meet your problems, however unusual.

WRITE TO SPECIAL PROJECTS DEPT. A. W. FOR FURTHER INFORMATION

AVICA CORPORATION
P. O. BOX 1090
PORTSMOUTH, RHODE ISLAND
TEL. PORTSMOUTH 479

two discussion periods. The speaker was thanked by S/L E. McCullough.

Philadelphia Section

Emily R. Gibbs, *Secretary*

Brigadier General Thomas J. DuBose, Commander of the Air Rescue Service, USAF, gave an exceedingly fine presentation of the Rescue Service before a group of 130 members at the Engineers' Club on October 7. In part, the General spoke as follows:

"The Air Rescue Service was organized May 29, 1946, as a new part of the United States Air Force to be devoted full time to aiding air crews in distress, to finding them when they get lost, and to returning them to safety.

"The Air Rescue Service is only 7 years old, yet already its tally of rescues runs into the thousands. Not all of those whom we have assisted have been military personnel, for we respond to calls for help wherever we may be, regardless of the race or calling of the person in distress. Primarily, of course, our job is to aid the military. . . . In the 3 years of the Korean war, the 3rd Air Rescue Group retrieved 996 men from behind enemy lines and rescued or evacuated 8,684 from other areas there. . . . Because ours is a humanitarian nation and especially because we are a humanitarian rescue service, we aid any others as best we can when we are called upon. We have been called upon for rescue work in such disasters as the Kansas floods of 1951; an outbreak of yellow fever in Costa Rica the same year; the floods and storms that ravaged the coasts of England and the Netherlands last winter; and, more recently, the earthquake-torn Greek Islands in the Ionian Sea a few months ago. We sent rescue aircraft from England, the Continent, and from North Africa to carry food and medicines, doctors and supplies to the Greek islands, and these same aircraft carried injured survivors away to safety.

"Where our rescue organizations operated in the last war as individual units, the Air Rescue Service is a cohesive service that operates around the world. This world map that I am about to show you indicates the locations of our eleven Air Rescue Group Headquarters and of their Air Rescue Squadrons and shows their very large areas of responsibility. In addition, the 14th Air Rescue Group is being organized at Palm Beach International Airport. We operate from the blistering deserts of Saudi Arabia in the Middle East to the Yellow Sea in the Far East and from the arctic regions of the North to the domain of our friendly neighbors in South America. Within the United States we have two Air Rescue Groups covering the ZI, Canada, and Mexico. The rest are scattered where most needed all around the world. Of the two Groups in the ZI, one—the 5th—has headquarters and one squadron at Westover AFB, Massachusetts. Its other three squadrons are at Selfridge AFB, Michigan; Maxwell AFB, Alabama; and Ellington AFB, Texas. The 46th Air Rescue Squadron, stationed at Westover AFB at Chicopee, Mass., is responsible for search and rescue missions in all of New England, New York, and Pennsylvania and as far south as North Carolina. It is a large area of responsibility, for it includes a wide area of the Atlantic Ocean too. . . . The other Air Rescue Group in the ZI—the 4th—has its headquarters and one squadron at Hamilton AFB, California. Its other three rescue squadrons are at Lowry AFB, Denver, Colorado; March AFB, California; and McChord AFB, Washington."

The meeting closed with the showing of a movie, *Project Hop-A-Long*, followed by a discussion period.

San Diego Section

E. R. Hinz
Corresponding Secretary

September activities of the San Diego Section consisted of a technical meeting and a dinner meeting held in the San Diego IAS Building.

On September 3, four representatives of the Narmco Company, manufacturers of reinforced plastics, presented a discussion of fiberglass reinforced plastics for aircraft use. W. D. Rainey talked in detail, accompanied by some well-prepared slides on the manufacture of fiberglass and its applications.

Fiberglass laminates are heterogeneous in character, consisting of glass filaments arranged in the desired weave (there are several weaves available depending on desirability of a grain in the final product) and a resin that may be a polyester, silicone, or phenolic. The resulting product is light and perfectly elastic with a modulus approximately the same as aluminum.

Reinforced fiberglass has a long list of advantages over other materials for aircraft use. Some of these are: high strength-weight ratio, good dielectric qualities, imperviousness to corrosion, high impact resistance, ability to be colored, good thermal dimensional stability, inexpensive tooling, and lack of critical materials.

After Mr. Rainey's detailed presentation, a panel of Narmco experts consisting of Messrs. W. S. Saville, E. Carmichael, and V. Ord answered questions from the floor. The speakers also had an exhibit of several dozen aircraft parts made by their company and others using fiberglass laminates.

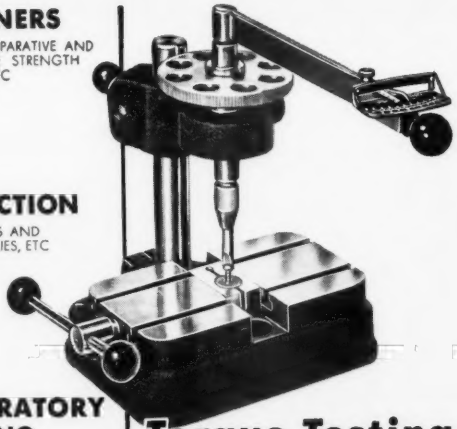
▶ The dinner meeting held on September 17 featured A. P. Higgins, Works Man-

DESIGNERS
for COMPARATIVE AND ULTIMATE STRENGTH TESTS, ETC

INSPECTION
of PARTS AND ASSEMBLIES, ETC

LABORATORY TESTING
of SCREWS
SOCKETS
TAPS
LOCK NUTS
DRIVING BITS
HAIR SPRINGS, ETC

PRODUCTION QUALITY CONTROL
for DELICATE OPERATIONS, ASSEMBLY OF FRAGILE MECHANISMS OR INSTRUMENTS; FOR FASTENERS IN PLASTICS AND LIGHT METALS.



Torque Testing FIXTURE

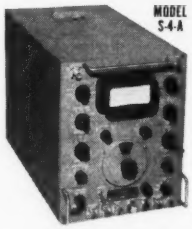
A universal fixture with 1000 uses. Holds driver in accurate alignment; in instrument bearings. Provides rapid engagement with test sample...torque is applied and measured with Sturtevant Torque Wrench.

Model TTF¼ *Capacity* **0-200 in. lbs.**
Model TTF½ *Capacity* **0-150 ft. lbs.**

Write for Bulletin TF

P.A. STURTEVANT CO.
ADDISON QUALITY ILLINOIS

THE SAR PULSESCOPE®
BY WATERMAN



MODEL S-4-A

Weight 31.5 lbs.
9⅛" x 11¼" x 17¼"

Another example of WATERMAN pioneering, a compact, portable instrument for precision pulse measurements adaptable for all electronic work, including radar and TV. S-4-A SAR PULSESCOPE will portray all attributes of the pulse; such as shape, amplitude, duration and time displacement. In S mode of operation, the unit functions as a wide band oscilloscope, with optional video delay, in either repetitive or triggered sweep conditions. In A mode of operation the unit functions as a precision time measuring device, with internal crystal controlled markers available for self calibration. In R mode of operation a desired small segment of A Sweep is expanded to fill the face of the tube for detailed observation.

Video Amplifier band pass up to 11 mc . . . optional Video delay 0.55 μs . . . Pulse rise and fall time better than 0.07 μs . . . Video sensitivity of 0.5 p to p/inch . . . S Sweep 80 cycles to 400 KC either triggered or repetitive . . . A Sweep 1.2 μs to 12,000 μs, R Delay 3 μs to 10,000 μs . . . Directly calibrated on a precision dial . . . R Pedestal (or sweep) 2.4 μs to 24μs . . . A & R Sweep Triggers available externally . . . Internal crystal markers of 10 μs ±50 μs . . . Built in precision amplitude calibration . . . Operates on 50 to 1000 cycles at 115V AC.

WATERMAN PRODUCTS CO., INC. PHILADELPHIA 25, PA.
CABLE ADDRESS: POKETSCOPE

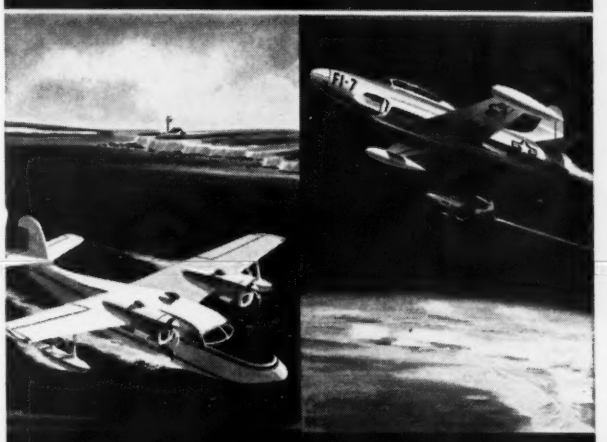
WATERMAN PRODUCTS INCLUDE:

S-4-A SAR	PULSESCOPE
S-5-A LAB	PULSESCOPE
S-10-B GENERAL	POCKETSCOPE
S-11-A INDUSTRIAL	POCKETSCOPE
S-14-A HIGH GAIN	POCKETSCOPE
S-14-B WIDE BAND	POCKETSCOPE

Also RAKSCOPES, LINEAR AMPLIFIERS, RAYONIC TUBES and other equipment

WATERMAN PRODUCTS

From Water Level To Stratosphere...



Pittsburgh FABSEAL

Makes Flying Safer... More Efficient!

Millions of flying hours prove the dependable performance of these impregnated fabric tapes in civilian and military use!

● Many of America's leading builders of aircraft use Pittsburgh's FABSEAL Tapes with complete confidence in their outstanding quality to seal flying boats, pressurized cabins and for other applications where there is considerable racking movement.

● FABSEAL Tapes are impregnated fabric of uniform density, resistant to water, gasoline and oil. They are available in .015" thickness and in widths from ½" to 12", packages in rolls of 50 feet.

● These tapes are particularly designed for use in fluid or air containers where excessive pressures are experienced. They are also adapted for sealing structural members where flexibility and vibration present unusual requirements. FABSEAL Tapes can also be bolted, riveted or screwed between metal, wood or fiber members to provide a fillet that assures a complete seal.

● Call on us for advisory service. Our wide experience in the aircraft field often can save you time and money.

PITTSBURGH PLATE GLASS CO., Industrial Paint Div., Pittsburgh, Pa. Factories: Milwaukee, Wis.; Newark, N. J.; Springdale, Pa.; Houston, Texas, Los Angeles, Calif.; Portland, Ore. Ditzler Color Div., Detroit, Michigan. The Thresher Paint & Varnish Co., Dayton, Ohio. Forbes Finishes Division, Cleveland, Ohio. M. B. Suydam Div., Pittsburgh, Pa.

PPG PITTSBURGH PAINTS
PAINTS • GLASS • CHEMICALS • BRUSHES • PLASTICS • FIBER GLASS
PITTSBURGH PLATE GLASS COMPANY

ager—Plant II, Convair, San Diego, in a talk on "Methods for Reducing Lead Time Between Design and Production." Mr. Higgins' main theme was the simultaneous development of tooling with engineering rather than a series operation.

Success of this system is based on the assumption that once a design is accepted such major tooling criteria as plant size and layout, assembly bucks, machine tools, and handling equipment do not materially change with detail design changes. Concerning tooling of detailed parts, Mr. Higgins advocates the transmittal of blueprints directly to tooling even before stress or other specialists have released them. In this manner, tooling has a jump on establishing its man-power needs, raw materials, and special purchases for jigs and fixtures. Formally released drawings serve as a final check on the tooling at a later date.

Reduction of lead time by this simultaneous tooling and engineering will be certain to yield some obsolete detailed tooling. However, the small amount of tooling requiring rework is insignificant when compared with the large saving in lead time which is an irreplaceable item.

The same dinner meeting was also the occasion for the presentation of the new officers. Dwight Bennett, Chairman of the Nominating Committee, presented the retiring Chairman R. P. White with the Chairman's key and introduced the following newly elected officers of this section: Chairman, Herman Braasch; Vice - Chairman, James G. Wenzel; Treasurer, Earl Hinz; Corresponding Secretary, Harry C. Matteson; and Recording Secretary, James Adamson.

Texas Section

Howard Marx
Outgoing Secretary

An election of officers for the 1953–1954 year resulted as follows: Chairman, Douglas G. Andreoli; Vice-Chairman, Howard F. Marx; Secretary, John H. Boucher; and Treasurer, George C. Grogan, Jr.

▶ "The Paris Air Show" was the theme of the September 24 dinner meeting of the Texas Section which was held at the Greater Fort Worth International Airport. Preceding the formal program was the Annual Business Meeting of the Texas Section.

Incoming Chairman Douglas Andreoli Assistant Project Engineer, Chance Vought Aircraft Division of United Aircraft Corporation, reviewed the progress of the Section during the term of the past administration. Monthly specialist meetings at Arlington State College were introduced and were well attended. The First Annual Southwestern Student Competition attracted students and faculty representatives from eleven colleges. The Awards Night Dinner, with the address by IAS President C. J. McCarthy, was the high point of last year's activities. Mr. Andreoli also reviewed the election procedure and the new Section Constitution. Concluding the business meeting, he expressed the sincere appreciation of all in the Texas Section for the outstanding leadership and untiring efforts of Outgoing Chairman William A. Clegern, to whom he presented the official IAS Chairman's key.

John J. Hospers, Assistant to Chance Vought's General Manager, used excellent colored slides to describe his recent trip to Europe and Africa. He described the Paris Air Show and the craft displayed there. Of special interest were pictures of the Dessault Mystere, the highly proclaimed French jet fighter. From Paris, Mr. Hospers journeyed to Tunisia to review operations of Chance Vought Corsairs by the French Air Force. He described the installations and the life and habits of both the military and the native people in this area. Pictures of the Casbah in Bizerte highlighted the presentation, inasmuch as the political unrest that followed the assassination of the Shah made the presence of "Yankees" rather hazardous. The slides of the Casbah, or native quarter, were of a high degree of technical excellence; Mr. Hospers declared, however, that they could not describe the place adequately because the camera was unable to record the odoriferous character of the atmosphere which permeated the whole area. Pictures taken on the return trip in Italy and in Holland concluded the presentation.

▶ On October 3, over 60 Texas Section members journeyed by automobile, bus, and airplane to the Ordnance Aerophysics Laboratory at Daingerfield, Tex., for the first field trip of the new season and one of the most interesting ever attended by Texas Section members.

The members were greeted at O.A.L. by Convair's R. J. Volluz, Chief of the Supersonic Wind Tunnel, and a well-qualified staff of guides and lecturers. The fact that all members attending passed through "Security" at the Confidential level in a matter of minutes was the first indication that a well-planned and superbly conducted tour awaited them. They visited the high-altitude and sea-level ram-jet engine test cells, the supersonic wind tunnel, the model shop, and the extensive IBM data reduction installation.

Novel ideas in test installations and data-gathering methods which were seen during the tour testified to the skill and ingenuity of the O.A.L. personnel. An automatic manometer board by which banks of manometers are scanned by photoelectric cells and the readings recorded on punched cards, was of special interest. This installation was designed and built at the laboratory. At the supersonic wind tunnel, where confidential tests were under way, Texas Section viewed an amazing schlieren display that presents the flow pattern in various colors. Areas of compression and rarefaction and the gradations between them appear in characteristic colors that are much easier to interpret than the normal black-and-white display. Color prints of several test configurations were also observed.

Extensive use of punched-card machines was apparent throughout the tour. Raw tunnel data are recorded and corrected on punched-card machines. An automatic plotting machine then plots the punched-card data to the scale requested by the user.

A color film describing the functional relationship between various parts of the physical plant was shown. The power plant, shared with the Lone Star Steel Company, which surrounds the Ordnance Aerophysics Laboratory, and the highlights of the installations that heat, dry, and cool the wind-tunnel air supply were vividly portrayed.

The tour of the Ordnance Aerophysics Laboratory was concluded with a luncheon for the visitors which featured steaks, Texas style. R. J. Volluz greeted the group officially for J. A. Arnold, Convair Division Manager, and announced "open house" to those who could remain for the rest of the afternoon. Howard Marx, acting for D. G. Andreoli, Texas Section Chairman, expressed the appreciation of the visitors for the great show staged by O.A.L. for their benefit and accepted a memento of the Field Trip in the form of a scroll from Mr. Volluz. The scroll will be placed permanently in the archives of the Texas Section.

Student Branches

Cal-Aero Technical Institute

James K. Carmody
Secretary-Treasurer

The Cal-Aero Student Branch September activities included a fine field trip out to the U.S. Naval Ordnance Test Station at Inyokern, Calif.

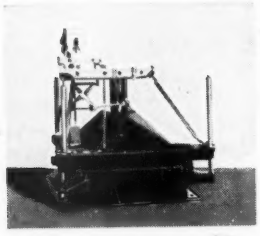
We arrived at the main gate with our security clearances and were promptly met by Dr. R. F. McElwee who was our genial host throughout the day.

aircraft performance measured and evaluated from the ground up!

Working on the ground, aerodynamics guards our defense in the air by assuring top aircraft performance. In this proud field of aviation "groundwork", Taller & Cooper Test Equipment is as versatile as aircraft itself.

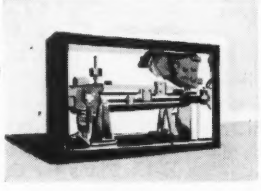
Each test instrument, whether designed or completely manufactured by Taller & Cooper, is specifically created for each individual application. Taller & Cooper's modern facilities and experienced Engineering Staff offer the fastest, surest performance control.

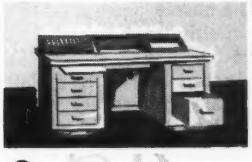
Let the Taller & Cooper Engineering Staff help you achieve accuracy from the ground up!


A

B

C


D


E

A WIND TUNNEL BALANCES
SUBSONIC • TRANSONIC • SUPERSONIC
PRECISION-AUTOMATIC-ELECTRIC-REMOTE

B DIGITAL CONVERTER

C PRECISION DYNAMOMETER TORQUE & THRUST MEASURING AND RECORDING EQUIPMENT

D INDICATING AND RECORDING SCALES
FOR STATIC W. T. PRESSURES
DIFFERENTIAL W. T. PRESSURES
MACH METER, TORQUE, THRUST, FORCES, MOMENTS

E REMOTE PRINTING DATA RECORDERS
FOR FORCES, MOMENTS, TEMPERATURES, PRESSURES, PHYSICAL QUANTITIES, ELECTRICAL QUANTITIES

WRITE TODAY for complete information

TALLER & COOPER, INC.
ENGINEERS • MANUFACTURERS

74 WASHINGTON ST. • BROOKLYN 1, N. Y.

This photograph, taken at the Naval Ordnance Test Station at Inyokern, Calif., shows the instructors and IAS student members of Cal-Aero Technical Institute on a field trip to the Inyokern last September. Kneeling in front of the group are, *from right to left:* Dr. E. F. McElwee, tour host; E. W. Robischon, IAS Western Region Manager; Harris Bode, Branch Faculty Advisor; James Bishop, Branch Chairman; James Carmody, Branch Secretary-Treasurer; Sam Genian, Branch Vice-Chairman; and two unidentified student members.

Dr. McElwee first took us through the entire unrestricted part of the ultra-modern Michelson Laboratory, after which we listened to two fine talks on the research and development of rocket-propelled missiles by T. Mico and B. Jaeger. We then saw a movie depicting life on the station, as well as some interesting rocket, torpedo, and guided-missile testing.

After lunch, Dr. McElwee took us on a tour through the Aeroballistics Laboratory. This was quite interesting from the standpoint that the missiles are fired through the building and are photographed from 48 stationed cameras that take an average of six exposures per camera. Compare this with the 1,000- to 2,000-ft. per sec. velocity of the missile, and one gets some idea of the multitude of electronic equipment involved.

We then were taken by bus to one of the many test ranges where we were treated to a ground rocket-firing demonstration. Everyone there instantly felt that it was a good thing the pilot of flight 223, the test plane, was on our side, for he demonstrated his deadly accuracy by firing a salvo of six rockets in the small test circle.

We then visited another test range where the rocket missiles are fired on an accurately laid railroad track. After each of the Student Members and instructors had thanked Dr. McElwee for his excellent program, the tour ended at 5:00 p.m.

Massachusetts Institute of Technology

John Stafford, *Secretary*

The October 6 meeting was opened by Chairman Milton Toorans with 60 persons present. An outline of the programs for the year was given by Vice-Chairman Bill Moody, who announced that speakers for the forthcoming meetings would include representatives from Bell Aircraft Corporation; Douglas Aircraft Company, Inc.; Lockheed Aircraft Corporation; and Piasecki Helicopter Corporation.

Vice - Chairman Moody also announced that M.I.T. would be host to the Second Annual Northeastern Student IAS Convention. The date decided upon is April 9–10, 1954.

United States Naval Academy

Robert M. Hemings, Jr., *Secretary*

The first meeting of the 1953–1954 school year was called to order by Chairman Don Walsh. The purpose of the meeting was to recruit new members in the freshman class. *Ski Jump Two*, a film depicting the use of skis in the arctic regions on P2V's and R4D's and the establishment of cold-weather observation stations, was shown to the 70 attending students.

▶ The second meeting was called on September 14, primarily to present a Bell Aircraft Corporation film on the X-1. Plans for the ensuing year were also discussed. Approximately 120 persons attended.

▶ Commander S. W. Kerkering, USN, Instructor in the Academy's Department of Marine Engineering, addressed the September 21 meeting on the subject, "Fighter Design in the Bureau of Aeronautics." Commander Kerkering was formerly attached to BuAer's Fighter Design Section and worked on the Douglas D558. Two hundred and fifty persons attended this meeting at which Chairman Walsh presided.

▶ The meeting of September 28 was called for the showing of a confidential film. Two hundred persons were present; Chairman Walsh presided.

IAS membership blanks were distributed to those persons who wished to join the U.S.N.A. Student Branch. At the same meeting, 140 names were listed of members who desired to make a field trip to the Naval Air Test Center at Patuxent River, Md., on October 31.

A short action movie, *Fury in the Pacific*, was shown.

University of Michigan

Donald E. Wilcox, *Secretary*

Before the close of the spring semester of the 1952–1953 school year, the following officers were elected for the ensuing year: Chairman, Kirk Comstock; Vice-Chairman, Ralston Schultz; Secretary, Donald Wilcox; and Treasurer, Donald Groesbeck. J. D. Schetzer, Associate Professor of Aeronautical Engineering, is the Honorary Chairman.

University of Tulsa

William A. Keeler
Secretary-Treasurer

The first meeting of the year was called to order at 7:30 p.m., September 24, by Chairman Jack Owens. The total attendance was 20.

The treasurer's report was read and approved. This was followed by a reading and discussion of the purposes and advantages of IAS membership in order to acquaint the new members with the functions of the Student Branch.

The election of a Vice-Chairman was taken up. However, the actual election was postponed until the next meeting so that new members might become better acquainted with the old members.

The subject of meeting dates was also discussed, with the third Thursday of the month being the final decision. The one exception to this was the meeting scheduled for October 8.

The meeting was brought to a close by a social period in which coffee and doughnuts were served. Two films of general interest were shown. The meeting was adjourned at 10:00 p.m.

West Virginia University

Benjamin D. Grove
Corresponding Secretary

An election of officers which was held on last May 20 had the following results: Chairman, Malcolm W. H. Ullock; Vice-Chairman, Charles R. Bartlett; Recording Secretary and Treasurer, James F. Heavner; and Corresponding Secretary, John Hesen. Professor Leon Z. Seltzer is the Honorary Chairman.

▶ On September 23, Chairman Ullock called the meeting to order and opened it for nominations for corresponding secretary. (Mr. Hesen, who had been elected to this position in the spring, had dropped out.) The election was close and was won by Benjamin D. Grove.

Chairman Ullock then introduced all visitors and members who were present. After the introductions were completed, the meeting was turned over to Professor Seltzer who gave a brief outline of the aims and ideals of the IAS.

A film on the Bristol Brabazon brought the meeting to a close.

Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Elected to Associate Fellow Grade

Butterfield, John P., Master of Automotive Engrg., Chief Design Engr., Missile Branch, Chrysler Corp.

Plantema, Frederik J., Dr. of Tech. Science, Chief, Struct. Sect., National Luchtvaart Laboratorium.

Transferred to Associate Fellow Grade

Blatz, William J., B. of Ae.E., Chief of Wind Tunnel Testing, Airplane Engrg. Div., McDonnell Aircraft Corp.

Brush, Robert P., A.A., Engrg. Test Pilot & Operational Engr., Douglas Aircraft Co., Inc. (Santa Monica).

Clauser, Milton U., Ph.D., Head, School of Aeronautics, Purdue Univ.

Pierce, Ernest W., M.A. (Math.), Design Specialist-Aerodynamic Design Group Leader, Douglas Aircraft Co., Inc.

Young, Raymond W., M.E., Pres. & Gen. Mgr., Reaction Motors, Inc.

Elected to MEMBER Grade

Abels, Alan W., B.S.M.E., Asst. V.-P. & Asst. to Dir. of Contracts, Consolidated Vultee Aircraft Corp.

Alexander, Wayne D., B.S.M.E., Research Group Engr., Consolidated Vultee Aircraft Corp. (Daingerfield).

Baxter, Ralph F., B.S. in M.E., Proj. Engr., Aircraft Div., Rheem Manufacturing Co.

Bergstrom, B. Einar, M.S. in Ae.E., Aero. Engr., SAAB Aircraft Co.

Christensen, Grant D., A.B., Asst. to V.-P.—Engrg., Consolidated Vultee Aircraft Corp. (San Diego).

Dorris, Harry W., B.S., Design Devel. Engr., Weapons Systems Evaluation Section, The Glenn L. Martin Co.

Dougherty, Cecil W., Standards Engr., Hardman Tool & Engrg. Co.

Du Lyn, F. W., B.S. in Ae.E., Chief, Airlines Engrg., United Aircraft Service Corp.

Faber, Norman A., Hydraulics Design Group Engr., Lockheed Aircraft Corp. (Burbank).

Falk, L. Ericsson, Pres. & Gen. Mgr., Telektron AB (Stockholm).

Fulton, David C., B.S.E.E., Aviation Mgr., Pacific Coast Region, Westinghouse Electric Corp.

Halbert, Kurt P., B. of M.E., Tech. Engr., ANPP, Design Engrg., General Electric Co.

Harris, Lloyd, Production Test Pilot, Lockheed Aircraft Corp. (Marietta).

Hubbard, Herbert L., Engrg. Designer "A," Northrop Aircraft, Inc.

Kelber, Charles C., M.S. in Theoretical & Applied Mechanics, Member, Propulsion Section, Aircraft Div., The RAND Corp.

Kulkarni, S. R., B.Sc. Engrg., Aero. Engr., Hindustan Aircraft, Ltd.

Lin, Hua, M.S., Proj. Engr., Aeroelastic & Struct. Research Lab., Massachusetts Institute of Technology.

Lopez, Raul, Aircraft & Engine Maint. Instructor, ICAO, TAB.

Michielsen, Herman F., Dipl. Bau-Ing., Struct. Engr., Struct. Research Group, Lockheed Aircraft Corp. (Burbank).

Molella, Ross J., M.S. in Ae.E., Supervisory Aircraft Struct. Devel. Engr. GS-12, NAES, NAMC (Philadelphia).

Parks, Edwin K., Ph.D., Asst. Prof.—Aerodynamics, Univ. of Kansas.

Ramsey, Samuel D., Design Engr., North American Aviation, Inc. (Los Angeles).

Scales, J. Kenneth, Engr. (Admin.), Exp. Sect., Canadair, Ltd.

Sobolewski, Jerzy Jozef, M.E., Group Leader, Engrg. Dept., Canadair, Ltd.

Strong, Herbert D., Jr., B.S., Head, Design Group, Wind Tunnel Section, Jet Propulsion Lab., California Institute of Technology.

Taylor, George W., B.S., Sales Engr., Sales Div., Boeing Airplane Co. (Seattle).

Transferred to MEMBER Grade

Brantley, James Q., Jr., Ph.D. in E.E., Assoc. Electronics Engr., Cornell Aeronautical Laboratory, Inc.

Fink, Daniel J., S.B. & S.M. in Ae.E., Proj. Engr., Allied Research Associates, Inc.

Gross, William A., Ph.D., Asst. Prof., Iowa State College.

Hama, Francis R., Ph.D., Research Engr., Iowa Institute of Hydraulic Research, State University of Iowa.

Hoexter, Rolf, M.M.E., Asst. Proj. Engr., Wright Aero. Div., Curtiss-Wright Corp.

Jenny, Robert B., B. of Ae.E. Aerodynamicist, Douglas Aircraft Co., Inc. (Long Beach).

Kainer, Julian H., M.S. in Ae.E., Aerodynamics Engr. "A," Ryan Aeronautical Co.

Kemp, Nelson H., Ph.D. in Ae.E., Aero. Engr., Research Dept., United Aircraft Corp.

Kenny, Thomas M., B.S. in Ae.E., Sr. Struct. Engr., The Glenn L. Martin Co.

Kirchner, Mark E., M.Sc., Aerodynamics Engr. "B," Boeing Airplane Co. (Seattle).

Knodel, David C., M.Ae.E., Sr. Engr., Allied Research Associates, Inc.

Lobrecht, Dorr, Jr., M. of Engrg., Head of Scheduling & Report Checking (Test Engr. "A,"), Consolidated Vultee Aircraft Corp. (Daingerfield).

Marte, Jack E., M.S. in Ae.E., Proj. Engr., Jet Propulsion Lab., California Institute of Technology.

McCullough, Edward E., B.A.Sc., Asst. Resident Engrg. Officer, Sq. Leader, RCAF.

Musil, Jay L., B.S.Ae., Sr. Aero. Engr., Aerophysics Sect., Cook Research Labs. Div., Cook Electric Co.

Presnal, Allister L., B.Sc., Design Engr., Greenwood & Co.

Quillinan, John Henry, B. of Ae.E., Proj. Engr., Applied Research Branch, Aero. Lab., David Taylor Model Basin.

Rizika, Jack W., M.Sc. in Ae.E., Proj. Analyst, The Glenn L. Martin Co.

Rosenberg, Richard H., B.Aero.E., Controls Group Leader, General Electric Co.

Sander, William B., B. of Ae.E., Struct. Devel. Engr., Boeing Airplane Co. (Seattle).

Steele, Joseph R., B.Sc. in Engrg., Production Control & Engrg. Officer, USCG. Aircraft Repair & Supply Base (North Carolina).

Taylor, James Lee, M.S. in Ae.E., Research Engr., Prelim. Analysis, North American Aviation, Inc. (Downey).

Wollner, Bertram C., B.A.E., Aircraft Struct. Loads Engr., Struct. Branch, Design Elements Div., Bureau of Aeronautics, Dept. of the Navy.

Elected to Associate Member Grade

Clemente, L. Gary, LLB., V.-P., in Charge of R&D, Unexcelled Chemical Corp.

Cooper, Frank, V.-P.—Sales, Hydro-Aire, Inc.

Kramer, Marvin W., Dept. Head, East Coast Aeronautics, Inc.

Lounsbury, Harry M., Exec. Secy., American Helicopter Society.

Nemac, William, B.S. (Education), Training Specialist (Instructor), North American Aviation, Inc. (Columbus).

Newhall, Wilson V., Brig. Gen. & Commanding Officer, 126th Fighter Bomber Wing, III, ANG, State of Illinois, Military & Naval Dept.

Parkin, Don, Aircraft Sales Mgr., Taylor Forge & Pipe Works; Pres. & Co-Owner, Sunset Sales Corp.

Rios, Edward, Tech. Writer, Northrop Aircraft, Inc.

Elected to Technical Member Grade

Frazier, Donald N., Flight Engr., Pan American World Airways.

Gottlieb, Theodore D., Design Layout-Asst. Proj. Engr., Pacific Airmotive Corp.

Hayward, R., Engr., Special Weapons Dept., Canadair, Ltd.

Luedde, John C., B.S.M.E., Jr. Engr., Analysis Group, Propulsion Sect., Guided Missiles Div., Bendix Products Div., Bendix Aviation Corp.

Stanfield, William G., S.B. in M.E., Systems Engr., Chance Vought Aircraft Div., United Aircraft Corp. (Dallas).

Transferred to Technical Member Grade

Allen, John S., B.S. in Ae.E., Proj. Engr., Met-L-Wood Corp.

Baker, Kemper W., B.S., Maj., USAF; Exec. Officer, Advisory Group for Aero. R&D, NATO (Paris).

Barnes, George A., B.S., Assoc. Engr.-Aerodynamicist, Applied Physics Lab., The Johns Hopkins Univ.

Baz, Nicolas G.

Bracha, Vincent J., B.S., Maj., USAF; Aero. Engr., USAF Institute of Technology, Wright-Patterson AFB.

Brestel, Pliny C., B.S. in Ae.E., Jr. Production Engr., Aeronca Manufacturing Corp.

Cassler, Luther H., M.S. (Aero.), 1st Lt. & Pilot, USAF; Instructor—Mathematics, USMA (West Point).

Charles, John M., B.S. in Ae.E., Lt., USN; Graduate Student, California Institute of Technology.

Couture, Roger J., B. of Ae.E., Aerodynamicst "C," North American Aviation, Inc. (Downey).

Crenshaw, William P., B.S. in Ae.E., Lt., USN.

Di Pietro, Frank J., B. of Ae.E., Engrg. Draftsman "B," North American Aviation, Inc. (Los Angeles).

Dubinsky, Robert G., B. of Ae.E., Stress Analyst, Thieblot Aircraft Co., Inc.

File, Warren H., B.S. in Ae.E., Rocket Test Engr., Bell Aircraft Corp.

Flinn, Evard H., B.S., Aero. Engr., WADC, Wright-Patterson AFB.

Garred, Mathew D., Jr., B.S., Exp. Test Standards Engr., Allison Div., General Motors Corp.

Green, Joseph, B.S., Maj., USAF; Aircraft Maint. Officer, 305 B.W., McDill AFB.

Haslett, Hugh J., B.S., Maj. & Sr. Pilot, USAF; Production Planning & Procurement Officer, AMC, Wright-Patterson AFB.

Holbrook, David A., Jr. Engr., Chance Vought Aircraft Div., United Aircraft Corp.

Hostetler, Robert J., B. of Ae.E., Ens. & Pilot, USN (Naval Air Station, Hutchinson, Kan.).

Kuzma, Robert L., B. of Ae.E., Flight Research Engr., Sikorsky Aircraft Div., United Aircraft Corp.

Lavelle, Joseph E., Jr., B. of Ae.E., Jr. Engr., Chance Vought Aircraft Div., United Aircraft Corp.

Lindsley, Jack N., A.E., Lt., USN; Engrg. Officer, O. & R. Dept., Naval Air Station (Lakehurst).

Long, Lawrence J., B.S.

McCubbin, Stacy E., B.S. in Ae.E., Production Liaison Engr., Douglas Aircraft Co., Inc. (Tulsa).

Melnik, Walter L., M.S. in Ae.E., Engr., Rosemount Research Center, Univ. of Minnesota.

Miller, Ralph S., B.S. in Ae.E., Struct. Engr., Consolidated Vultee Aircraft Corp. (Ft. Worth).

Parham, James L., B. of Ae.E., Jr. Engr.—Stress Analysis, Chance Vought Aircraft Div., United Aircraft Corp.

Penn, James P., B. of Ae.E., Aerodynamic Devel. Engr., ADC, Wright-Patterson AFB.

Pincus, Leonard C., B. of Ae.E., Engrg. Trainee, Republic Aviation Corp.

Rast, James J., B.S. in Ae.E., 2nd Lt., USAF.

Schurmann, Ernest, S.M., Aerodynamics Engr., Consolidated Vultee Aircraft Corp. (Ft. Worth).

Smith, Donald L., B.S. in Ae.E., Aero. Engr.—R&D, Goodyear Aircraft Corp.

Starr, Harry E., B.S., Jr. Engr.—R&D, Bendix Aviation Corp.

Stephenson, Wayne L., B. of Ae.E., Capt., Aero. Engr. & Pilot, USAF.

Thompson, Kenneth O., B.S., Jr. Engr., Rosemount Research Labs., Univ. of Minnesota.

Tinnan, Leonard M., B.S. in Ae.E., 2nd Lt., USAF; Aero. Engr.—R&D, Wright-Patterson AFB.

West, David E., B.S. in Ae.E.

White, Donald D., B.S. in Ae.E., Ens. & Naval Officer, USN (U.S.S. "Black").

Wohlen, Richard L., A.E., Pvt., 85th Inf. Reg., 10th Inf. Div., Ft. Riley (Kansas).

Wood, William P., B.S., Maj. & Sr. Pilot, USAF; Aero. Engr., Edwards AFB.

Youth, Stanley, B. of Ae.E., Aerodynamicist, Bell Aircraft Corp.

Suggestion for Binding
Issues of the Aeronautical Engineering Review

Arrangements have been made so that our readers may have their issues of the Review bound carefully and economically in our authorized binding. Simply write for details to:

AIRE
P.O. Box 776
Highland Park, Illinois

Staff Engineer ARMAMENT

We have an attractive opening for a staff specialist in the design of aircraft armament systems, armor, and their installations. Duties include responsibility for evaluating various aircraft armament systems, the preparation of basic armament design specifications and the technical direction and administration of armament testing.

Applicants should have experience as an engineering specialist in a large design organization. Job requirements include engineering degree plus eight to ten years' experience in various aircraft armament fields, such as aircraft guns, ammunition chutes, ammunition feeders (including related pneumatics) and rockets (including pack design).

All inquiries will be held confidential. For further consideration submit letter of application to:

ENGINEERING PERSONNEL SECTION

CHANCE VOUGHT AIRCRAFT

P. O. Box 5907 Dallas, Texas

DIVISION OF UNITED AIRCRAFT CORPORATION

MIDWEST RESEARCH INSTITUTE

Kansas City, Mo.

has career openings

in its

ENGINEERING AND APPLIED PHYSICS DIVISIONS

for

MECHANICAL ENGINEERS
ELECTRICAL ENGINEERS
ENGINEERING ANALYSIS
APPLIED PHYSICISTS

for

RESEARCH AND DEVELOPMENT WORK IN BROAD TECHNICAL FIELDS

Please write or call Martin Goland, Associate Director for Engineering Sciences, Midwest Research Institute, 4049 Pennsylvania Ave., Kansas City, Mo. Phone: LOgan 0203.

STRESS ANALYST

Permanent Position
with Engineering Firm
Specializing in the
Design & Development of
Oil Refineries & Chemical Plants

PhD IN MATHEMATICS PREFERRED

This is a permanent position on the engineering staff of a large East Coast organization known the world over for accomplishments in the petroleum and chemical industries.

We offer a high salary, a liberal pension plan and many other employee benefits.

Please write details of experience, education, salaries received and initial salary requirements. Complete privacy is assured. Our personnel know of this opening.

Box #221, Room 1201

230 West 41 St., New York 36

Engineers Join the Sabre Builders

Insure your future with North American Aviation. The Engineering Department has challenging openings for engineers with aircraft experience, for recent grads... for men from other fields with adaptable experience. Twenty-five years of engineering vision and expansion and long term military projects secure your future. Openings now in:

THERMODYNAMICS • AERODYNAMICS
SYSTEM ANALYSIS • STRUCTURES
SERVO-MECHANISMS • ELECTRONICS
SPECIALISTS IN ALL MAJOR AIRCRAFT FIELDS

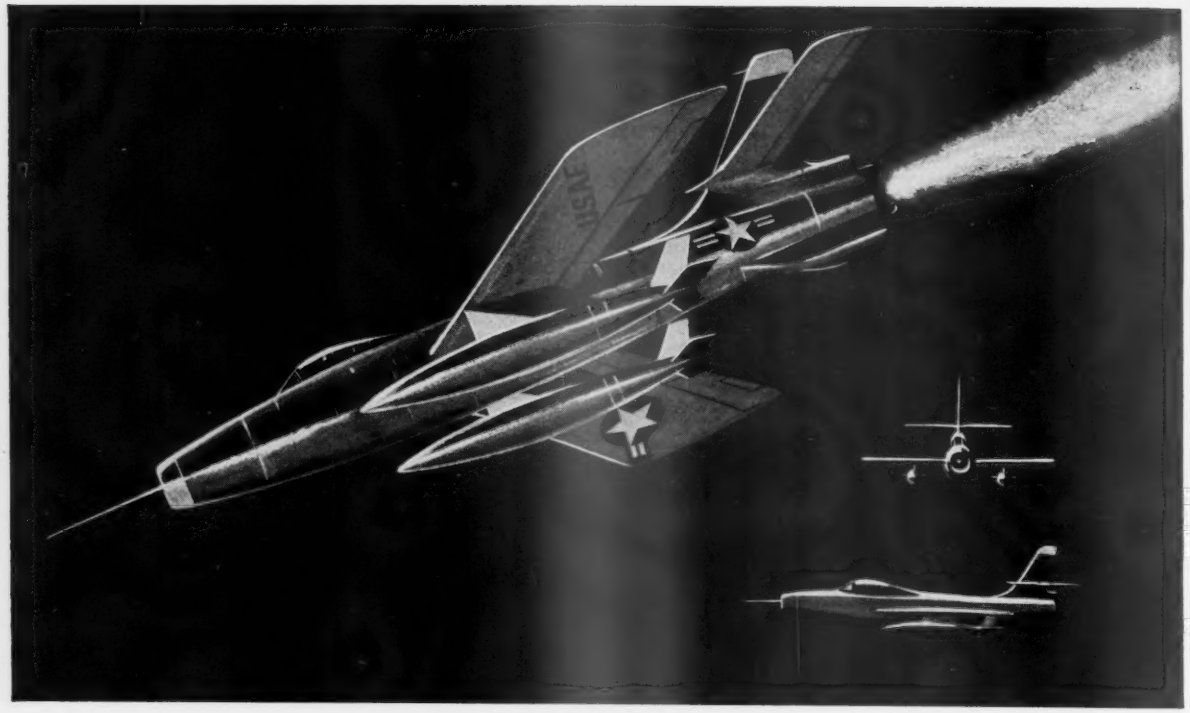
Liberal travel and moving allowances

Write to

North American Aviation, Inc.

Section 1
Engineering Personnel Office
Los Angeles International Airport
Los Angeles 45, California
or
Columbus 16, Ohio

NORTH AMERICAN HAS BUILT MORE AIRPLANES THAN ANY OTHER COMPANY IN THE WORLD



Republic XF-91

Rocket-powered, Supersonic, and Combat-Ready

Republic Aviation's XF-91 is the first American rocket-powered fighter-type aircraft to fly faster than the speed of sound. Yet it can also move so slowly that other jet fighters would have difficulty trailing it.

This fast-or-slow characteristic comes from its inverse tapered wings with leading edge slots . . . and the fact that the angles of swept-back wings can actually be varied in flight.

Monstrous power for the XF-91's supersonic research flights comes from three sources: A General Electric J-47, 5,200-pound thrust turbojet; an afterburner; and a 6,000-pound thrust rocket engine built by Reaction Motors, Inc. Together, they can push the XF-91 up to extremely high speed.

In its flight through the sound barrier, the XF-91 gets assistance from Inco Nickel and the Inco Nickel Alloys. These are used in vital engine parts and other places where combinations of corrosion resistance, heat resistance, strength and ductility are demanded.

Perhaps you have a metal problem calling for properties like these. Inco's Technical Service Section will gladly assist you in finding a solution. Write to them for the information you want.

WHERE INCO NICKEL ALLOYS ARE USED IN THE XF-91

Inconel®
- Combustion liners, domes, transition sections and cross-over tubes
- Lock wire (above 800°F.)
- Afterburner igniter plugs

Inconel "W"®
- Afterburner shell
- Afterburner structural members

Inconel "X"®
- Springs
- Gaskets
- Rocket engine turbine wheel

Monel®
- Rivets
- Lock wire
- Small diameter fuel tubing

Nickel
- Spark plug parts
- Ignition system

Nickel and Monel are also used in much of the accessory equipment such as instrumentation and electrical and electronic gear.

Inco Nickel Alloys

MONEL® • "R"® MONEL • "K"® MONEL • "KR"® MONEL "S"® MONEL • INCONEL® • INCONEL "X"® INCONEL "W"® • INCOLOY® • NIMONIC® Alloys NICKEL • LOW CARBON NICKEL • DURANICKEL®

INCO

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street New York 5, N. Y.

Aeronautical Reviews

A Guide to the Current Literature of Aeronautical Research and Engineering

I. PERIODICALS AND REPORTS

Aerodynamics 288
Boundary Layer & Thermoaerodynamics 288
Control Surfaces 288
Fluid Mechanics & Aerodynamic Theory 289
Internal Flow 289
Performance 289
Stability & Control 289
Wings & Airfoils 291

Aeroelasticity 291

Air Transportation 292

Airplane Design 292

Aviation Medicine 293

Computers 293

Education & Training 293

Electronics 293
Antennas 293
Circuits & Components 293
Construction Techniques 295
Electronic Controls 295
Electronic Tubes 295
Measurements & Testing 295
Navigation Aids 296
Radar 296
Wave Propagation 297

Equipment 297
Electric 297
Hydraulic & Pneumatic 297

Flight Operating Problems 297
Ice Prevention & Removal 297

Flight Safety & Rescue 297

Fuels & Lubricants 297

Instruments 297
Pressure-Measuring Devices 297
Recording Equipment 298

Machine Elements 298
Bearings 298
Rotating Discs & Shafts 298

Materials 298
Corrosion & Protective Coatings 298
Metals & Alloys 298
Metals & Alloys, Ferrous 298
Metals & Alloys, Nonferrous 298
Nonmetallic Materials 299
Testing 299

Mathematics 299

Mechanics 299

Meteorology 299

Missiles 299

Navigation 299

Photography 299

Power Plants 300
Jet & Turbine 300
Rocket 300

Production 300
Metalworking 302

Propellers 302

Reference Works 302

Rotating Wing Aircraft 302

Space Travel 302

Structures 302
Beams & Columns 302
Elasticity & Plasticity 303
Plates 303
Testing 303

Thermodynamics 303

Wind Tunnels & Research Facilities 303

II. BOOK REVIEWED IN THIS ISSUE

Human Factors in Air Transportation. Ross A. McFarland 305

Reviewed by Dr. Stephen J. Zand, Research and Development Board, Washington, D.C.

Book Notes 305

Books, reports, and periodicals reviewed in this issue or in previous issues may be borrowed on 2-week loan without charge by individual or Corporate Members of the Institute in the U.S. and Canada. Members of The Paul Kollsman Lending Library who are not Members of the Institute may borrow books and, in special cases, other research material. Members of the IAS may borrow also from the Engineering Societies Library through The Paul Kollsman Lending Library.

Photostatic copies of material in the Institute's libraries may be obtained at a cost of $0.35 to members and Corporate Members ($0.45 to nonmembers) for each $8^1/_2$- by 11-in. print and $0.40 to members and Corporate Members ($0.50 to nonmembers) for each $11^1/_2$- by 14-in. print, plus postage. A minimum charge of $1.00 is made to nonmembers of the IAS.

Bibliographies on special subjects will be compiled at the rate of $2.50 per hour. *Translations* of technical literature from foreign languages may be obtained at $12 to $14 per 1,000 words, depending on the language. IAS members receive a 20 per cent discount on bibliographies and translations.

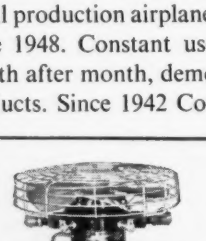
Full information about library membership and facilities will be sent upon request to The Paul Kollsman Lending Library, 2 East 64th St., New York 21, N.Y.

McDONNELL F2H BANSHEES—*Outstanding Navy Fighters*

CORNELIUS PNEUMATIC SYSTEMS
Contribute to the Outstanding Success of

McDONNELL
FIGHTERS

McDONNELL has been using Cornelius Air Compressors on all production airplanes since 1948. Constant use, month after month, demonstrates the reliability of Cornelius products. Since 1942 Cornelius has built thousands of high pressure air compressors for the leading aircraft manufacturers, Navy and Air Force. Profit from this experience—write to us about your pneumatic equipment requirements.



CORNELIUS COMPRESSOR
4CFM . . . 3000 PSI
Powered by integral hydraulic motor. Other models available with various pumping capacities. All compressors can be furnished with either hydraulic motors, DC electric motors or AC 400 cycle motors.

THE Cornelius COMPANY
MINNEAPOLIS 21, MINNESOTA
Pioneers in the Development of
AIRCRAFT PNEUMATIC SYSTEMS

Aerodynamics

The N.L.L. Card Catalogue of Aerodynamic Measurements. A. C. de Kock and A. I. van de Vooren. *Netherlands, NLL Rep. F. 125a*, June 20, 1953. 48 pp. Lists in appendixes include: symbols for forces, moments, and connected quantities; incompressible, subsonic, transonic, and supersonic flow characteristics; geometrical symbols; the figure code; and abstracted periodicals and reports.

Boundary Layer & Thermoaerodynamics

Boundary-Layer Flow along a Flat Plate with Uniform Suction. J. M. Kay *Gt. Brit., ARC R&M 2628* (May, 1948), 1953. 28 pp. BIS, New York. $1.70.

Interactions Between Wholly Laminar or Wholly Turbulent Boundary Layers and Shock Waves Strong Enough to Cause Separation. G. E. Gadd. *J. Aero. Sci.*, Nov., 1953, p. 729. 12 refs. NPL investigation and qualitative analysis.

An Investigation of the Use of an Auxiliary Slot to Re-establish Laminar Flow on Low-Drag Aerofoils. R. W. Cumming, N. Gregory, and W. S. Walker. *Gt. Brit., ARC R&M 2742* (Mar., 1950), 1953. 14 pp. BIS, New York. $1.00.

On the Stability of Laminar Boundary Layer Flow. Sin-I Cheng. *Quart. Appl. Math.*, Oct., 1953, p. 346. ONR-USAF-supported investigation.

Heat Transfer and Skin Friction by an Integral Method in the Compressible Laminar Layer with a Streamwise Pressure Gradient. Ivan E. Beckwith. *U.S., NACA TN 3005*, Sept., 1953. 55 pp. 27 refs.

Note on the Effect of Variable Wall Temperature on Heat Transfer; Addendum to "Heat Transfer Calculation for Aerofoils" (R. & M. 1986, Nov. 1942). H. B. Squire. *Gt. Brit., ARC R&M 2753* (Oct., 1950), 1953. 2 pp. BIS, New York. $0.05.

Skin Friction and Heat Transfer for Laminar Boundary-Layer Flow With Variable Properties and Variable Free-Stream Velocity. S. Levy and R. A. Seban. *J. Appl. Mech.*, Sept., 1953, p. 415. 13 refs.

An Experimental Investigation of the Influence of Strong Adverse Pressure Gradients on Turbulent Boundary Layers at Supersonic Speeds. Georg Drougge. *Sweden, Flygtekniska Försökanstalten, FFA Meddelande NR 46*, 1953. 22 pp. 20 refs.

A Study of Shock Wave Turbulent Boundary Layer Interaction at M = 3. S. M. Bogdonoff, C. E. Kepler, and E. Sanlorenzo. *Princeton U. Dept. Aero. Eng. Rep. 222*, July, 1953. 29 pp. ONR-USAF-sponsored theoretical and experimental investigation of viscous effects in supersonic flows at the Gas Dynamics Lab., Forrestal Research Center.

Control Surfaces

The Aerodynamic Characteristics of Flaps. A. D. Young. *Gt. Brit., ARC R&M 2622* (Feb., 1947), 1953. 55 pp. 138 refs. BIS, New York. $3.50. Review of the literature covering investigations and developments.

High-Speed Tunnel Tests of a 5 per cent Chord Dive-Recovery Flap on a NACA

0015 Aerofoil. D. A. Clark. *Gt. Brit., ARC R&M 2689* (June, 1948), 1953. 19 pp. BIS, New York. $1.25. Tests at Reynolds Number of 1.4×10^6 as the Mach Number varies between 0.30 and 0.80 for pressure plotting.

Fluid Mechanics & Aerodynamic Theory

Airflow About Cone-Cylinders with Curved Shock Waves. V. E. Bergdolt. *J. Aero. Sci.*, Nov., 1953, p. 751. 12 refs. Theoretical and experimental interferometric investigation, at Aberdeen's Ballistics Research Labs., of flows over cone-cylinder models in free flight covering the region of detached shocks to the establishment of completely supersonic Taylor-Maccoll flow.

Applications of Hypersonic Thin-Body Theory. Milton D. Van Dyke. *IAS Annual Summer Meeting, Los Angeles, July 15–17, 1953, Preprint 410.* 24 pp. 18 refs. Members, $0.50; Nonmembers, $0.85. Investigation of the simplest inviscid approximation theory retaining essential nonlinearities at Mach Numbers greatly exceeding unity.

Axisymmetric Flow of an Ideal Incompressible Fluid About a Solid Torus. E. Sternberg and M. A. Sadowsky. *J. Appl. Mech.*, Sept., 1953, p. 393. 16 refs. Solution based on the use of toroidal coordinates given in terms of Legendre functions of fractional order.

A Method of Solution of the Equations of Classical Gas-Dynamics Using Einstein's Equations. G. C. McVittie. *Quart. Appl. Math.*, Oct., 1953, p. 327.

New Experiments on Impact-Pressure Interpretation in Supersonic and Subsonic Rarefied Air Streams. F. S. Sherman. *U.S., NACA TN 2995*, Sept., 1953. 73 pp. 19 refs.

An Analysis of Laminar Free-Convection Flow and Heat Transfer About a Flat Plate Parallel to the Direction of the Generating Body Force. Simon Ostrach. (*U.S., NACA TN 2635*, 1952.) *U.S., NACA Rep. 1111*, 1953. 17 pp. 13 refs. Supt. of Doc., Wash. $0.20.

Temperature Distribution in the Wake of a Heated Sphere. D. H. Baer, W. G. Schlinger, and V. J. Berry. *J. Appl. Mech.*, Sept., 1953, p. 407. 33 refs. Theoretical and experimental study, with details of the apparatus.

Note on the Mean Square Value of Integrals in the Statistical Theory of Turbulence. C. C. Lin. *Quart. Appl. Math.*, Oct., 1953, p. 367.

Similarity Theory of Isotropic Turbulence. Appendix—On the Establishment of the Universal State. J. C. Rotta. *J. Aero. Sci.*, Nov., 1953, p. 769. 15 refs. Theoretical representation to show that an arbitrary homogenous and isotropic turbulent motion tends toward a universal state in which all statistical properties are determined by only three magnitudes; comparisons with experimental observations.

"Sonic Bangs"; Some Comments Regarding Their Nature and Origin. Tore R. Gullstrand. *Saab Sonics*, No. 19, 1953, p. 18.

Turbulence in Supersonic Flow. Leslie S. G. Kovásznay. *J. Appl. Sci.*, Oct., 1953, p. 657. Johns Hopkins University experimental investigations on the three modes of disturbance fields utilizing hot-wire anemometer measurements.

Internal Flow

Analysis of Viscous Laminar Incompressible Flow Through Axial-Flow Turbomachines With Infinitesimal Blade Spacing. T. P. Torda, H. H. Hilton, and F. C. Hall. *J. Appl. Mech.*, Sept., 1953, p. 401. Extension of the Lorenz theory.

Some Tests on Compressor Cascades of Related Aerofoils having Different Positions of Maximum Camber. A. D. S. Carter. *Gt. Brit., ARC R&M 2694* (Dec., 1948), 1953. 17 pp. BIS, New York. $1.25.

The Theoretical Pressure Distributions around some Conventional Turbine Blades in Cascade. T. J. Hargest. *Gt. Brit., ARC R&M 2765* (Mar., 1950), 1953. 19 pp. BIS, New York. $0.75.

The Effect of Boundary Layer on Sonic Flow Through an Abrupt Cross-Sectional Area Change. Robert S. Wick. *J. Aero. Sci.*, Oct., 1953, p. 675. 15 refs. CIT experimental investigation using a two-dimensional flow channel; qualitative analysis of results to devise a "jet-pump" concept.

Experiments on Conical Diffusers. H. B. Squire. *Gt. Brit., ARC R&M 2751* (Nov., 1950), 1953. 18 pp. BIS, New York. $1.25. Analysis of diffuser characteristics to determine effects of Reynolds Numbers between 5×10^4 and 10^6 on efficiency for uniform entry flow.

Experiments with Static Tubes in a Supersonic Airstream. I, II. D. W. Holder, R. J. North, and A. Chinneck. *Gt. Brit., ARC R&M 2782* (July, 1950), 1953. 14 pp. BIS, New York. $1.00. Tests at Mach Number 1.6 and Reynolds Number of 3×10^4, with pressure measurements in the vicinity of a shock wave close to a wall.

Laminar Flow in Channels with Porous Walls. Abraham S. Berman. *J. Appl. Phys.*, Sept., 1953, p. 1232. Solution of the Navier-Stokes equations for the case of a fluid withdrawn through the channel walls.

Two-Dimensional Flow Through a Diffuser With an Exit Length. K. R. Galle and R. C. Binder. *J. Appl. Mech.*, Sept., 1953, p. 390. Experimental investigation on basic diffuser flow efficiency problems.

An Analysis of Turbojet-Engine-Inlet Matching. DeMarquis D. Wyatt. *U.S., NACA TN 3012*, Sept., 1953. 19 pp. Representation of inlet air-flow capacities by the same parameter used to represent engine air-flow requirements to determine simply the inlet operational condition.

Theoretical Performance Characteristics of Sharp-Lip Inlets at Subsonic Speed. Evan A. Fradenburgh and DeMarquis D. Wyatt. *U.S., NACA TN 3004*, Sept., 1953. 21 pp. Method, based on a simple momentum balance analysis, to compute inlet pressure recovery, mass-flow relations, and additive-drag coefficients for forward subsonic velocities.

Evidences of an Inherent Error in Measurement of Total-Head Pressure at Supersonic Speeds. James S. Murphy. *Aero. Eng. Rev.*, Nov., 1953, p. 47. Nozzle design and calibration data obtained in an intermittent 8- by 13-in. supersonic wind tunnel at the University of Michigan.

An Introduction to the Method of Characteristics; An A.R.C. Paper in which the Method is Developed from Elementary Physical Considerations. R. Harrop. *Aircraft Eng.*, Sept., 1953, p. 277. Application to the study of a typical nozzle; analysis of the Prandtl-Meyer expansion relationship.

Performance

An Analysis of the Steady Climbing Turn Without Sideslip. J. R. Baxter. *Australia, ARL Rep. A. 81*, Dec., 1952. 31 pp.

The Effect of Compressibility on the Attitude of Aircraft in Rectilinear Flight. K. J. Lush. *Gt. Brit., ARC R&M 2776* (Mar., 1948), 1953. 7 pp. BIS, New York. $0.65. Application of results of linear perturbation theory; deductions compared with the results of attitude measurements on a spitfire IX.

Energy Approach to the General Aircraft Performance Problem. Edward S. Rutowski. *IAS Annual Summer Meeting, Los Angeles, July 15–17, 1953, Preprint 420.* 28 pp. Members, $0.50; Nonmembers, $0.85. Analysis of basic performance elements; derivation of the classical climb and range equations.

Stability & Control

Application of Several Methods for Determining Transfer Functions and Frequency Response of Aircraft from Flight Data. John M. Eggleston and Charles W. Mathews. *U.S., NACA TN 2997*, Sept., 1953. 74 pp. 18 refs.

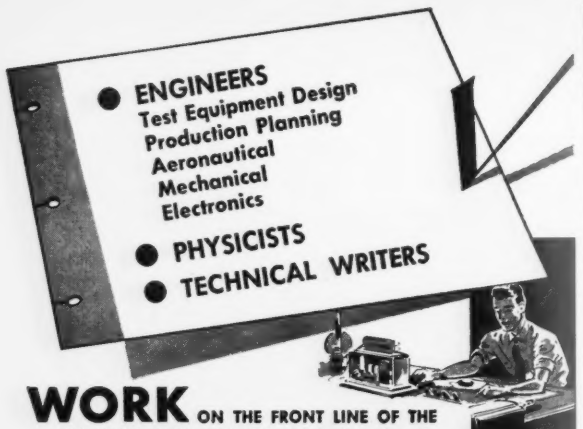
Effect of Aspect Ratio on the Low-Speed Lateral Control Characteristics of Untapered Low-Aspect-Ratio Wings Equipped with Flap and with Retractable Ailerons. Jack Fischel, Rodger L. Naeseth, John R. Hagerman, and William M. O'Hare. (*U.S., NACA TN 2347, 2348*, 1951.) *U.S., NACA Rep. 1091*, 1952. 47 pp. 22 refs. Supt. of Doc., Wash. $0.40. Includes design charts based on experimental results.

The Effect of Slipstream on the Longitudinal Stability of Multi-engined Aircraft. D. E. Morris and J. C. Morrall. *Gt. Brit., ARC R&M 2701* (Nov., 1948), 1953. 8 pp. 20 refs. BIS, New York. $1.00.

Effects of Symmetric and Asymmetric Thrust Reversal on the Aerodynamic Characteristics of a Model of a Twin-Engine Airplane. Kenneth W. Goodson and John W. Draper. *U.S., NACA TN 2979*, Sept., 1953. 67 pp.

Some Basic Concepts for Analyzing Dynamic Flight-Test Data. H. Klein and R. Sedney. *J. Aero. Sci.*, Nov., 1953, p. 740. Determination of the coefficients of the differential equations of a dynamic system to describe the aerodynamic stability derivatives of an aircraft.

A Theoretical Analysis of the Effects of Fuel Motion on Airplane Dynamics. Albert A. Schy. (*U.S., NACA TN 2280*, 1951.) *U.S., NACA Rep. 1080*, 1952. 22 pp. Supt. of Doc., Wash. $0.25.



WORK ON THE FRONT LINE OF THE NATION'S VITAL DEFENSE PROGRAM. Sandia Corporation is engaged in the development and production of atomic weapons—a challenging new field that offers opportunities in research and development to men with Bachelor's or advanced degrees, with or without applicable experience. Here you can work with able colleagues, eminent consultants and superior facilities on advanced projects of high importance — and also build a permanent career in a rapidly expanding field with a company that recognizes individual ability and initiative.

LIVE IN ALBUQUERQUE, THE HEART OF THE SUNNY SOUTHWEST. Located in the historic Rio Grande Valley at the foot of the Sandia Mountains, mile-high Albuquerque is famous for its climate—mild, dry and sunny the year around. A modern, cosmopolitan city of 150,000, Albuquerque offers unique advantages as a place in which to live. Albuquerque's schools, churches, theaters, parks, and modern shopping facilities afford advantages of metropolitan life—yet hunting, fishing, skiing and a multitude of scenic and historic attractions may all be found within a few hours' drive of the city. New residents have little difficulty in obtaining adequate housing.

ENJOY THESE OTHER IMPORTANT ADVANTAGES. These are permanent positions with Sandia Corporation, a subsidiary of the Western Electric Company, which operates Sandia Laboratory under contract with the Atomic Energy Commission. Working conditions are excellent and salaries are commensurate with qualifications. Liberal employee benefits include paid vacations, sickness benefits, group life insurance, and a contributory retirement plan. This is not a Civil Service appointment.

Make Application to:

PROFESSIONAL EMPLOYMENT
DIVISION E

SANDIA *Corporation*

SANDIA BASE ● ALBUQUERQUE, NEW MEXICO

DESIGN ENGINEERS
STRESS ENGINEERS
DESIGN LAYOUT ENGINEERS
FIELD ENGINEERS

FOR THE
DESIGN & DEVELOPMENT OF PROPULSION SYSTEMS

Previous experience with conventional and unconventional power plant design and development programs or related fields essential.

Fields of propulsion includes reciprocating and gas turbine engines.

LOCATION EASTERN UNITED STATES

Forward complete resume to:
Box ARE 1842, 221 W. 41st St., N. Y. 36
All replies confidential

Mechanical Engineer with Aerodynamic training or Aeronautical Engineer to work with Chief Aerodynamicist in Design of Axial Flow Fans, company now engaged in building fans for aircraft, power, naval and electronic industries. Excellent advancement possibilities. Salary attractive to qualified applicants. Send resume and photo to: PERSONNEL MANAGER, JOY MANUFACTURING COMPANY, NEW PHILA., OHIO.

NEEDED - - -
AUTHORITY ON AIRCRAFT ENGINES

Large aircraft manufacturer has a responsible position available in top echelon of engineering organization for man qualified as authority in the field of aircraft engines. Position will require individua of sound judgment and comprehensive knowledge of engine development programs. Prefer man with 15–25 years' background in the aircraft industry, most of which should have been with an engine manufacturer. Salary dependent upon qualifications. Please submit confidential resume with details of education and experience to Box 543, Aeronautical Engineering Review.

Wings & Airfoils

Chordwise and Compressibility Corrections to Slender-Wing Theory. Harvard Lomax and Loma Sluder. (*U.S., NACA TN 2295*, 1951.) *U.S., NACA Rep. 1105*, 1952. 19 pp. 23 refs. Supt. of Doc., Wash. $0.25.

A Comparison of Two Methods of Calculating Wing Loading with Allowance for Compressibility. Appendix: Note on Falkner's Method for Calculating Compressibility Effects on Wing Loading. V. M. Falkner and W. P. Jones. *Gt. Brit., ARC R&M 2685* (Oct., 1949), 1953. 53 pp. BIS, New York. $3.50.

Two-Dimensional Unsymmetric Flow Patterns at Mach Number 1. Gottfried Guderley and Hideo Yoshihara. *J. Aero. Sci.*, Nov., 1953, p. 757. Hodographic analysis of flow about symmetric slender profiles with a small angle of attack to compute the pressure distribution and lift curve slope.

The Effect of Compressibility on the Performance of a Griffith Aerofoil. H. H. Pearcey and E. W. E. Rogers. *Gt. Brit., ARC R&M 2511* (Nov., 1946), 1953. 30 pp. 13 refs. BIS, New York. $1.80.

The Effects of Camber on the Variation with Mach Number of the Aerodynamic Characteristics of a 10-Percent-Thick Modified NACA Four-Digit-Series Airfoil Section. Albert D. Hemenover. *U.S., NACA TN 2998*, Sept., 1953. 34 pp.

Note on the Application of Busemann's Formula to a Simple Two-Dimensional Curved Aerofoil Section. J. A. Dunsby. *J. RAeS.*, Sept., 1953, p. 600.

Surface Slopes and Curvatures of the RAE 100–104 and Other Rooftop-type Aerofoil Sections. J. Williams and Edna M. Love. *Gt. Brit., ARC CP 129* (Oct. 13, 1952), 1953. 11 pp. BIS, New York. $0.75.

Tests of the NACA 0010-1.50 40/1.051 Airfoil Section at High Subsonic Mach Numbers. Albert D. Hemenover. *U.S., NACA RM A53G09*, Sept., 4, 1953. 18 pp.

Wind-Tunnel Tests of the Stalling Properties of an 8 per cent Thick Symmetrical Section with Nose Suction Through a Porous Surface. R. C. Pankhurst, W. G. Raymer, and A. N. Devereux. *Gt. Brit., ARC R&M 2666* (June, 1948), 1953. 14 pp. BIS, New York. $1.00.

A Calculation of the Complete Downwash in Three Dimensions due to a Rectangular Vortex. Doris E. Lehrian. *Gt. Brit., ARC R&M 2771* (Mar., 1949), 1953. 41 pp., folded charts. BIS, New York. $3.50.

The Calculation of Lift Taking Account of the Boundary Layer. J. H. Preston. *Gt. Brit., ARC R&M 2725* (Nov. 21, 1949), 1953. 40 pp. 20 refs. BIS, New York. $2.45. Theoretical prediction of sectional characteristics to determine the behavior of a wing of finite span.

The Distribution of Lift over the Surface of Swept Wings. D. Küchemann. *Aero. Quart.*, Aug., 1953, p. 261.

Lift and Pitching Moment at Low Speeds of the NACA 64A010 Airfoil Section Equipped with Various Combinations of a Leading-Edge Slat, Leading-Edge Flap, Split Flap, and Double-Slotted Flap. John A. Kelly and Nora-Lee F. Hayter. *U.S., NACA TN 3007*, Sept., 1953. 45 pp. An approximate empirical method to determine the slat position to produce the highest maximum section lift coefficient for a given slat deflection angle.

The Measurement of the Overall Drag of an Aircraft at High Mach Numbers. D. J. Higton, R. H. Plascott, and D. A. Clarke. *Gt. Brit., ARC R&M 2748* (Jan., 1949), 1953. 22 pp. BIS, New York. $1.40.

Measurements of Maximum Lift on 26 Aerofoil Sections at High Mach Number. I—Tests on 19 Aerofoils. J. A. Beavan, R. Sargent, R. J. North, and P. M. Burrows. **II—Tests on a Further 7 Aerofoils.** R. J. North and P. M. Burrows. *Gt. Brit., ARC R&M 2678* (Jan., 1948), 1953. 31 pp. 13 refs. BIS, New York. $1.90.

Method for Calculating Lift Distributions for Unswept Wings with Flaps or Ailerons by Use of Nonlinear Section Lift Data. James C. Sivells and Gertrude C. Westrick. (*U.S., NACA TN 2283*, 1951.) *U.S., NACA Rep. 1090*, 1952. 25 pp. Supt. of Doc., Wash. $0.25.

The Second-Order Lifting Pressure and Damping in Roll of Sweptback Rolling Airfoils at Supersonic Speeds. John C. Martin and Nathan Gerber. *J. Aero. Sci.*, Oct., 1953, p. 699.

The Solution of Lifting-Plane Problems by Vortex-Lattice Theory. V. M. Falkner. *Gt. Brit., ARC R&M 2591* (Sept., 1947), 1953. 30 pp. BIS, New York. $2.45.

Two- and Three-Dimensional Unsteady Lift Problems in High-Speed Flight. Harvard Lomax, Max. A. Heaslet, Franklyn B. Fuller, and Loma Sluder. (*U.S., NACA TN 2256, 2387, 2403*, 1951.) *U.S., NACA Rep. 1077*, 1952. 55 pp. 30 refs. Supt. of Doc., Wash. $0.45.

Experimental Investigation of Base Pressure on Blunt-Trailing-Edge Wings at Supersonic Velocities. Dean R. Chapman, William R. Wimbrow, and Robert H. Kester. (*U.S., NACA TN 2611*, 1952.) *U.S., NACA Rep. 1109*, 1952. 19 pp. Supt. of Doc., Wash. $0.25.

The Influence of Wedge Thermal Conductivity Upon the Surface Temperature Distribution of a Wedge with a Laminar Boundary Layer in Supersonic Flow. Henry W. Woolard. *Cornell Aero. Lab. Rep. CAL/CF 1991*, Feb. 10, 1953. 13 pp.

A Note on Subsonic Edges in Unsteady Supersonic Flow. John W. Miles. *Quart. Appl. Math.*, Oct., 1953, p. 363.

On Supersonic Flow Past an Oscillating Wedge. Milton D. Van Dyke. *Quart. Appl. Math.*, Oct., 1953, p. 360.

On the Low Aspect Ratio Oscillating Rectangular Wing in Supersonic Flow. John W. Miles. *Aero. Quart.*, Aug., 1953, p. 231. 15 refs.

A Simplified Method to Obtain the Load Distribution Corresponding to the Ackeret Region for Wings Having Arbitrary Source Distribution at Supersonic Speeds. Julian H. Kainer. *J. Aero. Sci.*, Nov., 1953, p. 749.

Effects of Finite Span on the Section Characteristics of Two 45° Sweptback Wings of Aspect Ratio 6. Lynn W. Hunton. *U.S., NACA TN 3008*, Sept., 1953. 32 pp.

Low-Speed Wind-Tunnel Tests on Two 45 deg Sweptback Wings of Aspect Ratios 4.5 and 3.0 (Models A and B). J. Trouncer and G. F. Moss. *Gt. Brit., ARC R&M 2710* (June, 1947), 1953. 43 pp. BIS, New York. $2.60.

Velocity Potential and Air Forces Associated with a Triangular Wing in Supersonic Flow, with Subsonic Leading Edges, and Deforming Harmonically According to a General Quadratic Equation. Charles E. Watkins and Julian H. Berman. *U.S., NACA TN 3009*, Sept., 1953. 61 pp.

Supersonic Flow Past Wing-Body Combinations. W. Chester. *Aero. Quart.*, Aug., 1953, p. 287. 18 refs.

Wing-Body Interference at Subsonic and Supersonic Speeds; Survey and New Developments. H. R. Lawrence and A. H. Flax. *IAS Annual Summer Meeting, Los Angeles, July 15–17, 1953, Preprint 426*. 107 pp. 56 refs. Review of available theories and extensions; Cornell Aero. Lab. investigations on symmetrical lift problems.

Aeroelasticity

Application of Experimental Aerodynamic Coefficients to Flutter Calculations. H. Bergh and J. Ijff. *Netherlands, NLL Rep. F.122*, Nov., 1952. 6 pp.

The Determination of the Natural Frequencies of a Full-Scale Airframe-Engine System by the Admittance Method. J. R. Forshaw and F. T. Mountford. *Gt. Brit., ARC R&M 2667* (July, 1948), 1953. 24 pp. BIS, New York. $1.50.

Influence of Compressibility on the Calculated Flexure-Torsion Flutter Speed of a Family of Rectangular Cantilever Wings. J. Ijff. *Netherlands, NLL Rep. F.118*, 1952. 16 pp. Calculations at Mach Numbers of 0, 0.5, and 0.7.

An Iterative Transformation Procedure for Numerical Solution of Flutter and Similar Characteristic-Value Problems. Myron L. Gossard. (*U.S., NACA TN 2346*, 1951.) *U.S., NACA Rep. 1073*, 1952. 45 pp. Supt. of Doc., Wash. $0.40.

Preliminary Investigation of the Effects of Cascading of the Oscillating Lift Force of an Airfoil Vibrated in Bending. Donald F. Johnson and Alexander Mendelson. *U.S., NACA RM E53F29*, Sept. 9, 1953. 15 pp.

A Steady-Flow Aeroelastic Study by Electrical Analogy. Robert H. Scanlan. *J. Aero. Sci.*, Oct., 1953, p. 691. The Malavard and Duquenne "lifting surface calculator" electrical tank as applied to steady-state problems.

The Vibration of Rotating, Tapered-Twisted Beams. G. W. Jarrett and P. C. Warner. *J. Appl. Mech.*, Sept., 1953, p. 381. Extension of the Myklestad adaptation of the Holzer method to calculate natural frequencies and mode shapes of various systems.

Wing-fuselage Flutter of Large Aeroplanes. W. P. Jones. *Gt. Brit., ARC R&M 2656* (Nov., 1947), 1953. 46 pp. BIS, New York. $2.75. A general theoretical method based on aircraft design data taking into account a large number of degrees of freedom.

STABILITY in flight
RECORDED ACCURATELY
By Century Model 409
RECORDING
OSCILLOGRAPH
The Century Model 409 Oscillograph was designed for operation under the most adverse conditions, especially where space and weight considerations are limited. It is a miniature, compact unit incorporating many features found in larger models. Records faithfully during accelerations and shock in excess of 20 G's. Its size and capacity make it especially desirable for use in missile launching, parachute seat ejection, flight test of helicopter and fighter aircraft and torpedo studies.
Century GEOPHYSICAL CORPORATION
TULSA, OKLAHOMA
29-46 Northern Blvd. Long Island City, N. Y.
4447 No. Bodine Philadelphia 40, Pa.
3406 W. Washington Blvd. Los Angeles 16, Calif.
238 Lafayette St. Dayton 2, Ohio
504 Interurban Bldg. Dallas, Texas
EXPORT OFFICE 109 Broadway, N. Y. City

Air Transportation

The Aircraft Weight Problem in Airline Operation. R. F. Hassler. *Aeronautics*, Sept., 26, 1953, p. 106. Payload vs. service weight and other commercial transport problems.

Civil Jet Operations. A. M. A. Majendie. *J. RAeS.*, Sept., 1953, p. 539; Discussion, p. 555. BOAC operational experiences with the Comet I; cruising control and performance, landing and take-off, traffic control, meteorological, navigational, economic, and other aspects.

Report of the First Year's Activities of the National Air Transport Coordinating Committee. C. E. Rosendahl. *Address, Wings Club, New York*, May 20, 1953. Survey of operational and other problems including noise abatement and safety.

Airplane Design

An Approach to Light Aeroplane Design Problems. L. G. McFarlane. *Aeronautics*, Sept. 26, 1953, p. 115, cutaway drawing. Discussion of basic design, choice of materials, and types of structures in terms of performance and operational efficiency, with specifications and other technical data on the LGM-2 Peewit.

The Complexity of Simplification. William I. Stieglitz. *Skyways*, Oct., 1953, p. 14. Reliability and safety requirements in design simplification.

DC-3 Take-Off. Charles F. Banfe, Jr. *Skyways*, Oct., 1953, p. 24. Operational performance specifications.

Design for Production. W. E. W. Petter. *Interavia*, No. 9, 1953, p. 531. Analysis of weight reduction and cost problems in the design of fighter aircraft.

A Discussion on Fatigue. I—Fatigue. H. L. Cox. **II—Fatigue from the Metallurgist's Viewpoint.** E. R. Gadd. **III—Fatigue in Engine Design.** F. M. Owner. **IV—Fatigue in Aircraft Design.** B. E. Stephenson. **V—Summary of Discussions.** W. Tye. *J. RAeS.*, Sept., 1953, pp. 559, 565, 580, 584, 589. 81 refs. Held at University College, London, Mar. 27, 1953.

Escape from Aircraft by Downward Ejection. Walter S. Rothwell and Edward G. Sperry. *J. Av. Med.*, Aug., 1953, p. 322. Aeromedical viewpoint on specialized problems, including harness-suspension design and support of the extremities.

Fifty Years of Undercarriage Development. III, IV, V. *The Engr.*, Sept. 4, 11, 18, 1953, pp. 295, 329, 370. 13 refs. Dowty development of liquid-sprung units, with designs and diagrams; military and other applications and potentialities.

The Flying Boxcars. Beverly A. Dodge. *Hydraulic Engr.*, Aug.–Sept., 1953, p. 4. Development, design specifications, and performanee data.

From Idea to Attack Aircraft; How the Saab-32 Lansen Was Created. *Saab Sonics*, No. 19, 1953, p. 2. Design and structural details.

The Lockheed Super-Constellation 1049E. Stanley H. Evans. *The Aeroplane*, Aug. 28, 1953, p. 256. Develop-

mental survey; design features; weight analysis.

A Piston-engined Flying Target. *The Aeroplane*, Aug. 28, 1953, p. 260, cutaway drawing. M. L. Aviation's radio-controlled U.120 D, with design and structural features.

Three-way Guide to British Aircraft. *Aeronautics*, Sept., 1953, p. 54. Structural design survey of airplanes, helicopters, and engines, with performance data, diagrams, and drawings.

Aviation Medicine

Altitude Stress in Subjects with Impaired Cardiorespiratory Function; A Comparison of the Responses of Normal Subjects, Patients with Angina Pectoris, and Patients with Anemia to Hypoxia. John P. Marbarger, Pablo H. Wechsberg, Clarence V. Pestel, Gordon F. Vawter, and Sanford A. Franzblau. *J. Av. Med.*, Aug., 1953, p. 263. 38 refs.

Dynamic Centrifuge Trials of Anti-G Valves. R. A. Stubbs. *J. Av. Med.*, Aug., 1953, p. 334. Graphic presentation of test results by a photographic technique.

The Effect of High Breathing Pressure on Cardiac Output with and without Counter Pressure. Clarence C. Cain and D. I. Mahoney. *J. Av. Med.*, Aug., 1953, p. 308. 16 refs.

Neurocirculatory Collapse in Aircraft Flight; Report of a Case. Manah R. Halbouty. *J. Av. Med.*, Aug., 1953, p. 301.

The Operational Hazard of Microwave Radiation. Sidney I. Brody. *J. Av. Med.*, Aug., 1953, p. 328.

The Possibility of Cosmic-Ray Hazards in High Altitude and Space Flight. L. R. Shepherd. *J. Brit. Interplanetary Soc.*, Sept., 1953, p. 197. 15 refs.

Computers

The Correlatograph; A Machine for Continuous Display of Short Term Correlation. W. R. Bennett. *Bell System Tech. J.*, Sept., 1953, p. 1173. Details of apparatus and preliminary tests on an analog device to permit three-dimensional plotting.

Dead Programmes for a Magnetic Drum Automatic Computer. W. L. van der Poel. *Appl. Sci. Res., Sect. B*, No. 3, 1953, p. 190.

Fast-Acting Digital Memory Systems. I. Issac L. Auerbach. *Elec. Mfg.*, Oct., 1953, p. 100. Survey of devices based on magnetic principles.

First CEC Electronic Digital Computer Now Undergoing Final Tests, Packaging; Three Systems Under Construction Feature Speed, Capacity, Flexibility. *CEC Recordings*, Sept., 1953, p. 10.

Magnetic Memory Inventory. Craig Andrews and H. R. Quick. *Elec. Mfg.*, Oct., 1953, p. 124. Design of the American Airlines' Magnetronic Reservisor System.

SWAC—National Bureau of Standards Western Automatic Computer; Recent Developments and Operating Experience. *U.S., NBS Sum. Tech. Rep. 1807*, Sept., 1953. 13 pp.

Time-Base Generator for Control and Measurement. Ebrahim Nuban. *Tele-Tech*, Oct., 1953, p. 84. The Clary Multiplier Corp.'s preselect counter; application to analog-to-digital converters.

Education & Training

The C-124A Simulator. Herb Fisher. *Skyways*, Oct., 1953, p. 10. Evaluation of the realistic all-electronic Globemaster simulator; training techniques.

Electronics

The Application of Information Theory to Data-Transmission Systems, and the Possible Use of Binary Coding to Increase Channel Capacity. J. F. Coales. (*IEE Measurements Sect. Paper 1534.*) *Proc. IEE, Part III*, Sept., 1953, p. 291.

Communications Synchronizing Systems. F. T. Turner. *Elec. Eng.*, Oct., 1953, p. 874. Reexamination of synchronization systems in terms of the FM communication theory and as a servomechanism.

Capacitor-Modulated Wide-Range F-M System. Maurice Apstein and H. H. Wieder. *Electronics*, Oct., 1953, p. 190. Application in 50–500 mc. frequency range for multichannel telemetering and other circuits.

DC Selsyns and Annunciators for Aircraft. M. L. Allen and A. W. Eade. *Tele-Tech*, Oct., 1953, p. 100. High reliability telemetering devices, with two- and three-wire systems.

Measurements of Detector Output Spectra by Correlation Methods. Louis Weinberg and L. G. Kraft. *Proc. IRE*, Sept., 1953, p. 1157. Noise-analysis investigation at MIT of linear and square-law rectifiers.

A Statistical Study of Selective Fading of Super-High Frequency Radio Signals. R. L. Kaylor. *Bell System Tech. J.*, Sept., 1953, p. 1187. Investigation covering the 3750–4190 mc. range.

Transmission-Line Impedance and Efficiency. W. W. Macalpine. *Elec. Eng.*, Oct., 1953, p. 868. Abridged.

A Variation Formulation of the Multi-Stream Electrodynamic Field Equations. P. N. Butcher. *Philos. Mag.* (*7th Ser.*), Sept., 1953, p. 971. Development of the Hamilton-Jacobi theory of a rotational space charge stream.

Antennas

Aircraft Protection from Thunderstorm Discharges to Antennas. J. M. Bryant, M. M. Newman, and J. D. Robb. *Elec. Eng.*, Oct., 1953, p. 880.

A New Approach to the Design of Super-Directive Aerial Arrays. A. Bloch, R. G. Medhurst, and S. D. Pool. (*IEE Radio Sect. Paper 1536.*) *Proc. IEE, Part III*, Sept., 1953, p. 303.

Non-Resonant Sloping-V Aerial. J. S. Hall. *Wireless Engr.*, Sept., 1953, p. 223. Derivation of explicit formulas for the distant electric-field components at any azimuth and elevation.

Radiation Conductance of Axial and Transverse Slots in Cylinders of Elliptical Cross Section. James Y. Wong. *Proc. IRE*, Sept., 1953, p. 1172.

Vertically Polarized Microwave Antenna. R. K. Thomas and M. E. Ringenbach. *Radio & TV News, Radio-Electronic Eng. Sect.*, Oct., 1953, p. 13. Design details; performance and radiation pattern.

Circuits & Components

Basic Concepts in Circuit Analysis. D. W. Spence and C. R. Cahn. *Elec. Eng.*, Oct., 1953, p. 918. Abridged.

Delay Lines for Radar and Computers. Byron M. Cole and Melvin H. Murphy. *Tele-Tech*, Oct., 1953, p. 106. Application to pulse-forming networks, memory circuits, and compensation devices in NTSC filters and oscilloscopes.

Electronic Time Delay Relay Circuit. George H. Bateman. *Tele-Tech*, Oct., 1953, p. 94. Application to aircraft controls and indication systems.

A Random Walk Related to the Capacitance of the Circular Plate Condenser. E. Reich. *Quart. Appl. Math.*, Oct., 1953, p. 341.

Television Monitors Rocket Engine Flame. Frank A. Friswold. *Electronics*, Oct., 1953, p. 187. NACA propulsion research application; high-noise level, atmospheric corrosion, intensity of detail, and other factors; circuit details.

Termination Variation in the Constant-K Filter. Sidney C. Dunn. *Wireless Engr.*, Sept., 1953, p. 227.

Nonlinear Capacitors for Dielectric Amplifiers. George S. Shaw and James L. Jenkins. *Electronics*, Oct., 1953, p. 166. Details of a typical two-stage type producing 300 milliwatts output from a 0.3 milliwatt signal source.

Transient Analysis of Junction Transistor Amplifiers. W. F. Chow and J. J. Suran. *Proc. IRE*, Sept., 1953, p. 1125.

Artificial Dielectrics having Refractive Indices less than Unity. J. Brown. (*IEE Radio Sect. Monograph 62.*) *Proc. IEE, Part III*, Sept., 1953, p. 319. 22 refs. Abridged.

Electrets. G. G. Wiseman and E. G. Linden. *Elec. Eng.*, Oct., 1953, p. 869. Measurement of capacity; analysis of sources of electret materials and theoretical formation; applications.

Ferrite Applications at Microwave Frequencies. Dwight Caswell. *Electronics*, Oct., 1953, p. 246.

Radioactive Charging Effects with a Dielectric Medium. P. Rappaport and E. G. Linder. *J. Appl. Phys.*, Sept., 1953, p. 1110. Theoretical and experimental analysis of a new process to convert directly radioactive energy into electrical energy; application to the construction of a current source for electronic devices.

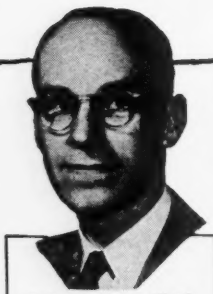
Some Dielectric Properties of Barium-Strontium Titanate Ceramics at 3000 Megacycles. Luther Davis, Jr., and Lawrence G. Rubin. *J. Appl. Phys.*, Sept., 1953, p. 1194.

Electromagnetic Scattering by an Ellipsoid in the Third Approximation. A. F. Stevenson. *J. Appl. Phys.*, Sept., 1953, p. 1143.

Evaluation of High Performance Magnetic Core Materials. I. Siefried R. Hoh. *Tele-Tech*, Oct., 1953, p. 86.

Engineers

AN INVITATION TO YOU TO GO PLACES WITH FAIRCHILD



Robert D. Gilson, Chief of Structures. Has worked on many top aviation projects in the aircraft industry, specializing in structural problems.

A secure future, exceptional opportunities for advancement, and a high starting salary await you at FAIRCHILD. We have openings right now for qualified engineers and designers in all phases of aircraft manufacturing.

Paid vacations, liberal health and life insurance coverage. Premium is paid when longer work week is scheduled.

ENGINE AND AIRPLANE CORPORATION
FAIRCHILD *Aircraft Division*
HAGERSTOWN, MARYLAND

A COMPLETE MEDIA PACKAGE
FOR YOUR
Aviation Marketing Program

AERONAUTICAL ENGINEERING REVIEW

For your monthly advertising message to the aircraft industry's engineering and design personnel—the men who influence buying.

1953
AVIATION
MARKET
GUIDE
Now Available!

24 pages of FACTS on your market and REVIEW.

Write for free copy TODAY!

AERONAUTICAL ENGINEERING CATALOG

Prefiles and distributes your aircraft products catalog to aviation's buyers and specifiers.

7,000 copies are distributed annually to aircraft engineers, designers, technicians and purchasing agents in all leading aircraft, engine and parts companies, Government aviation departments and leading air lines.

Write for your free copy of 12-page MARKET BOOK giving full details.

OFFICIAL PUBLICATIONS
INSTITUTE OF THE AERONAUTICAL SCIENCES
2 East 64th Street New York 21, N.Y.

Research Engineer

◆ ◆

Man to coordinate research program for a large progressive company in the field of propulsion including reciprocating engines, gas turbines, unconventional power plants and propellants. Requires a man interested in research with experience in directing research programs in propulsion or related field.

◆ ◆

All replies confidential.

Box AE 1730, 221 W. 41st St., N. Y. 36

Mechanical Engineer and Designer with several years' experience. To design heavy rotating equipment such as forced draft fans and other high pressure axial flow blowers, salary open, permanent position. Send resume and recent photo to:

PERSONNEL MANAGER
JOY MANUFACTURING CO.
NEW PHILA., OHIO

When you write to manufacturers whose advertising appears in the
Aeronautical Engineering Review,
it will be of interest to the companies
and of benefit to the Institute if you mention that you saw it
in the
Aeronautical Engineering Review

A Magnetic Amplifier for Synchros. R. L. Van Allen. *Elec. Eng.*, Oct., 1953, p. 925. Abridged. NRL development.

Magnets and Magnetism—Recent Developments. W. Sucksmith. *Brit. J. Appl. Phys.*, Sept., 1953, p. 257. 16 refs. An evaluation of ferromagnetic investigations, with an analysis of potentialities of new magnetic materials.

A Review of New Magnetic Phenomena. R. E. Alley, Jr. *Bell System Tech., J.*, Sept., 1953, p. 1155. 28 refs. Analysis of dimensional and domain wall motion effects, in the low megacycle region; ferromagnetic resonance and the Faraday effect, in the microwave region.

An Asymmetrical Finite Difference Network. R. H. MacNeal. *Quart. Appl. Math.*, Oct., 1953, p. 295.

A Method of Approximate Steady-State Analysis for Non-Linear Networks. G. R. Slemon. **Appendix.** G. H. Rawcliffe. (*IEE Paper 153.*) *Proc. IEE, Part I*, Sept., 1953, p. 275.

RLC Lattice Networks. Louis Weinberg. *Proc. IRE*, Sept., 1953, p. 1139. USAF-Army-ONR-supported research at MIT.

Theory and Application of Inert Networks; Use of Inert Networks for Solving Electrical Networks. N. F. Tsang. *U. Ark. Eng. Exp. Sta. Bul. 17*, June, 1953. 39 pp. Analysis of bilateral networks and of junction methods for practical calculations with numerical applications.

Transmission Characteristics of Nonsymmetrical Networks. Hans Klein. *Electronics*, Oct., 1953, p. 226.

Bridge-Stabilized Ultrasonic Oscillator. Louis W. Erath. *Electronics*, Oct., 1953, p. 174. With five overlapping frequency ranges up to 120,000 cycles per sec.; application to digital counters and audio and ultrasonic research.

A Controlled-Frequency Oscillator with Frequency "Memory." J. Van Bladel. *J. Sci. Instr.*, Sept., 1953, p. 299. Application to automatic control and other circuits.

Generating Nonlinear Functions with Linear Potentiometers. Harold Levenstein. *Tele-Tech*, Oct., 1953, p, 76. Application to computing and other systems.

A Graphical Spectrum Analyzer for Pulse Series. H. P. Raabe. *Proc. IRE*, Sept., 1953, p. 1129.

A Multichannel Time-Analyzer for Precision Work. G. von Dardel. *Appl. Sci. Res., Sect. B*, No. 3, 1953, p. 209. 15 refs. Development of 20- and 40-channel versions, with circuit details, for research and physical investigations.

Oscillator Switching for Variable Frequency Synchrotron Control. D. E. Caro and L. U. Hibbard. *Philos. Mag.* (*7th Ser.*), Sept., 1953, p. 964. With circuit details.

Sinusoidal and Relaxation Oscillations Sustained by Nonlinear Reactances. R. Stuart Mackay. *J. Appl. Phys.*, Sept., 1953, p. 1163.

Transistor Oscillators. Hans E. Hollmann. *Tele-Tech*, Oct., 1953, p. 82. Experimental investigation of the transistorized Hartley circuit at the Naval Air Missile Test Center, Point Mugu, Calif.

Kerosene Cooled Transistors. J. E. Maynard and R. L. Brock. *Electronics*, Oct., 1953, p. 202. Boeing research on the problem of self-heating of contacts in point-contact transistors.

A More Exact Treatment of the Equations Describing Dielectric Relaxation and Carrier Motion in Semiconductors. Julian Keilson. *J. Appl. Phys.*, Sept., 1953, p. 1198.

The Phase-Bistable Transistor Circuit. R. H. Baker, Irwin L. Lebow, Robert H. Rediker, and I. S. Reed. *Proc. IRE*, Sept., 1953, p. 1119. Details of a transistor-switching circuit; operational mode of the phase-bistable circuit; application to digital computers.

Semiconductor Diode Gates. Luther W. Hussey. *Bell System Tech. J.*, Sept., 1953, p. 1137. Methods of analysis to obtain practical first-order design, with experimental verification; application to pulse communication and computing devices.

Theoretical Resistivity and Hall Coefficient of Impure Germanium Near Room Temperature. P. G. Herkart and J. Kurshan. *RCA Rev.*, Sept., 1953, p. 427.

Transistors: Theory and Application. VIII—Small-Signal Transistor Operation. Abraham Coblenz and Harry L. Owens. *Electronics*, Oct., 1953, p. 158.

Construction Techniques

Forum on Printed Circuits. Edward Drinkwater, George de Beaumont, and Arnold Babbe. *SPE J.*, Oct., 1953, p. 11. Discussion on utilization of base materials and other problems, held at SPE Southern California Meeting, Feb., 1953.

(NavBuAer) Project Tinkertoy; Modular Design of Electronics and Mechanical Production of Electronics. *U.S., NBS Sum. Tech. Rep. 1824*, Sept., 1953. 15 pp. 13 refs.

Production Techniques in Transistor Manufacture; Point-Contact and Junction Transistors Require Germanium Slabs Cut from Single-Crystals of Controlled Impurity. James D. Fahnestock. *Electronics*, Oct., 1953, p. 130. Details of RCA processes.

Electronic Controls

Feedback Theory—Some Properties of Signal Flow Graphs. Samuel J. Mason. *Proc. IRE*, Sept., 1953, p. 1144. The equations of a systems problem expressed as a network of directed branches as in the block diagram of servomechanisms.

Quick Methods for Evaluating Closed-Loop Poles. G. A. Biernson. *Elec. Eng.*, Oct., 1953, p. 905. Abridged. Application to feedback control systems.

Static and Sliding Friction in Feedback Systems. J. Tou and P. M. Schultheiss. *J. Appl. Phys.*, Sept., 1953, p. 1210. Extension of conventional linear techniques of predicting system performance to the treatment of friction nonlinearity; theoretical results verified by analog computations.

Electronic Tubes

Acceleration Effects on Electron Tubes. F. W. Stubner. *Bell System Tech. J.*, Sept., 1953, p. 1203. 14 refs. Measurement of shock and vibratory accelerations in terms of performance and design criteria.

Applying Pulse Magnetrons to Radar Equipment. II. Charles V. Litton and Paul W. Crapuchettes. *Tele-Tech*, Oct., 1953, p. 102. Analysis of design errors underlying current reliability problems of absolute ratings; physical and mechanical environmental aspects.

Backward-Wave Tube. H. Heffner. *Electronics*, Oct., 1953, p. 135. For 6,000, 10,000, and 50,000 mc. applications.

Commercial, Ruggedized and Premium Tubes. Floyd A. Paul. *Electronics*, Oct., 1953, p. 212. CIT Jet Propulsion Lab. research covering reliability characteristics of tubes.

Crystallographic Variations of Field Emission from Tungsten. M. K. Wilkinson. *J. Appl. Phys.*, Sept., 1953, p. 1203. MIT investigation; construction of the experimental vacuum tube; development of a photometric method to measure light output from the phosphor.

Direct-Viewing Memory Tube. S. T. Smith and H. E. Brown. *Proc. IRE*, Sept., 1953, p. 1167. 14 refs. Modification of the Haeff "holding" beam tube.

Electron Flow Through Small Tubes with Magnetic Focusing. John L. Stewart. *J. Appl. Phys.*, Sept., 1953, p. 1236.

Gas-Discharge Tubes for Control of Microwave Attenuation. D. H. Pringle and E. J. Whitmore. *J. Sci. Instr.*, Sept., 1953, p. 320. Development for automatic gain control (AGC) purposes.

Influence of Secondary Electrons on Noise Factor and Stability of Traveling-Wave Tubes. R. W. Peter and J. A. Ruetz. *RCA Rev.*, Sept., 1953, p. 441.

Performance Evaluation of "Special Red" Tubes. H. J. Prager. *RCA Rev.*, Sept., 1953, p. 413. Quantitative analysis of characteristics of 10,000-hour-life tubes, with design criteria.

Physics in the Electronic Valve Industry. J. Thomson. *Brit. J. Appl. Phys.*, Sept., 1953, p. 262. Developmental and other problems in the production of thermionic, cathode-ray, photocell, flash, and other tubes.

Wide-Band Amplifiers Using Secondary-Emission Tubes. C. H. Chandler and G. D. Linz. *RCA Rev.*, Sept., 1953, p. 367. Details of an experimental tube having a grid-plate transconductance of 15,000 micromhos for use in amplifier circuits of general utility; applications.

Measurements & Testing

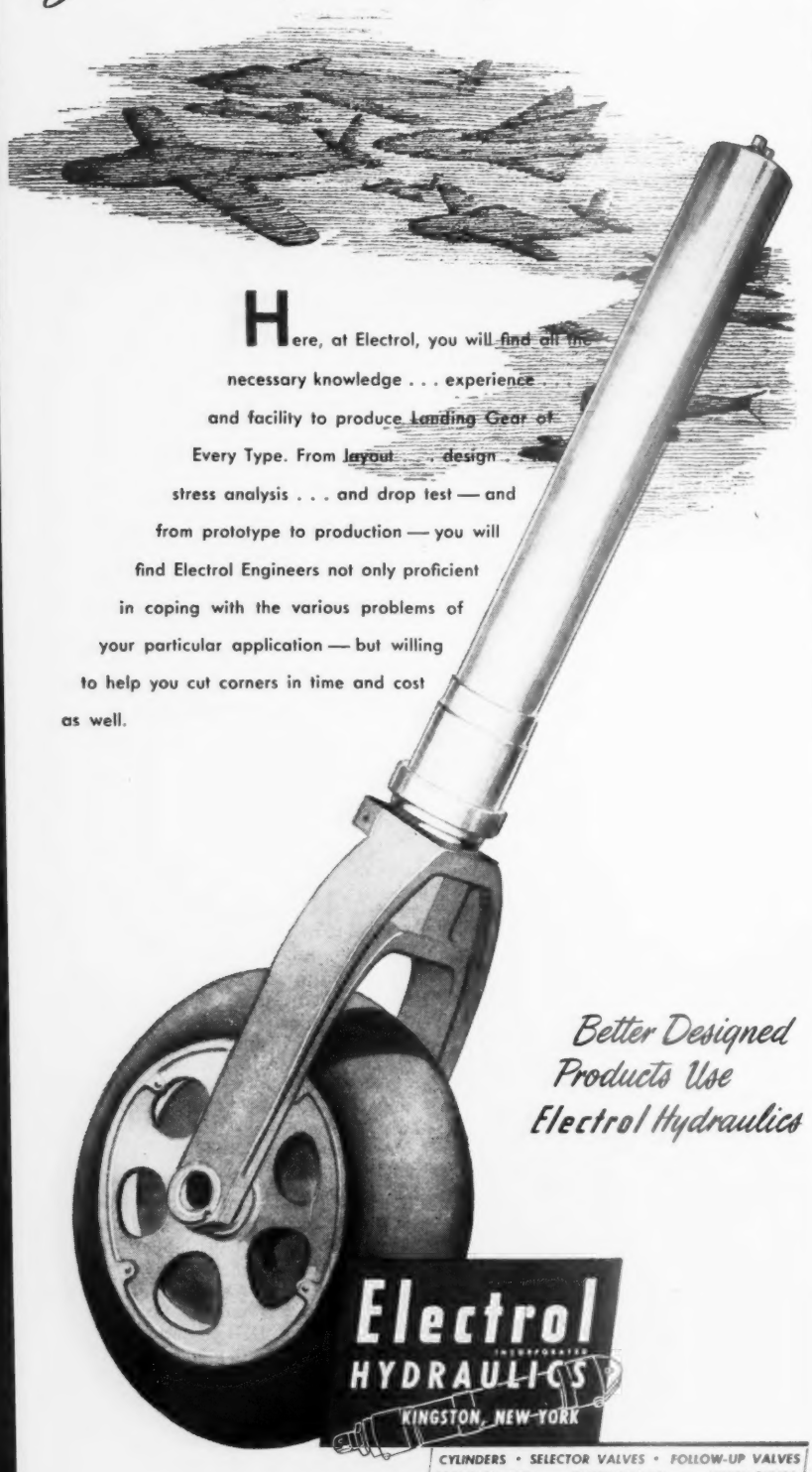
An AC-DC Gauss Meter. Alvin B. Kaufman. *Instruments*, Sept., 1953, p. 1360. Six basic techniques to measure magnetic flux; use of the bismuth "gauss effect."

Automatic Ionospheric Height Recorder; Frequency Range 0.65 to 25 Mc/s. C. Clarke and E. D. R. Shearman. *Wireless Engr.*, Sept., 1953, p. 211. Measuring apparatus incorporating the Naismith and Bailey receiving and recording circuit design.

Electrodynamic Microphonism in High-Sensitivity, Sub-Audio Frequency Measurements; A Note on Vibration Artifacts in Magnetic Environments and D-C Bias in Flying Laboratory Measurements and

LANDING GEAR OF EVERY TYPE

from Design to Flight



Here, at Electrol, you will find all the necessary knowledge . . . experience and facility to produce Landing Gear of Every Type. From layout . . . design . . . stress analysis . . . and drop test — and from prototype to production — you will find Electrol Engineers not only proficient in coping with the various problems of your particular application — but willing to help you cut corners in time and cost as well.

Better Designed Products Use Electrol Hydraulics

Electrol INCORPORATED HYDRAULICS KINGSTON, NEW YORK

CYLINDERS • SELECTOR VALVES • FOLLOW-UP VALVES
CHECK VALVES • RELIEF VALVES • HAND PUMPS
POWERPAKS • LANDING GEAR OLEOS • SOLENOID
VALVES • ON-OFF VALVES • SERVO CYLINDERS • TRANSFER
VALVES • CUT-OUT VALVES • SPEED CONTROL VALVES

Rocket Telemetry. J. W. Prast. *USAF SAM Project 21-38-001 Rep. 3*, Aug., 1952. 10 pp. 15 refs.

Measuring Impedance of High-Frequency Resistors. Charles L. Wellard. *Electronics*, Oct., 1953, p. 176. Army-USAF-sponsored development.

Microwave Measurements on Metallic Delay Media. Seymour B. Cohn. *Proc. IRE*, Sept., 1953, p. 1177. Measurement technique for the 4,500–6,500 mc. frequency range.

Mismatch Errors in Microwave Power Measurements. R. W. Beatty and A. C. MacPherson. *Proc. IRE*, Sept., 1953, p. 1112.

Permeameter for Radio Frequencies. G. P. McKnight. *Elec. Mfg.*, Oct., 1953, p. 150. NBS-developed design to test magnetic properties of a ferrite toroid.

A Review of Methods for Measuring the Constants of Piezoelectric Vibrators. Eduard A. Gerber. *Proc. IRE*, Sept., 1953, p. 1103. 26 refs.

Testing Electrical Instruments. F. D. Weaver. *Instruments*, Sept., 1953, p. 1362. Basic standards, circuit diagrams, and test procedures.

A Symmetrical Cathode Follower Bridge Circuit for Direct Spectrochemical Analysis. W. G. Walker and S. C. Baker. *J. Sci. Instr.*, Sept., 1953, p. 328. Circuit details; application to the determination of manganese in steels and generally to the comparative measurement of any two currents or potentials.

Navigation Aids

Accuracy and Utility of the VOR System. Frank C. White, Moderator, and others. *Skyways*, Oct., 1953, p. 20. Flight Operations Round Table discussion.

The Calculation of Wave-Interference Errors on a Direction-Finder Employing Cyclical Differential Measurement of Phase. W. C. Bain. (*IEE Radio Sect. Paper 1545.*) *Proc. IEE, Part III*, Sept., 1953, p. 253.

Lateral Separation and Theta-Theta Distance Measuring on Airways. B. O. Prowse. *The Log*, Sept., 1953, p. 222.

Some Practical Measurements of the Relative Performances of a Cyclical Phase-Comparison Type of Direction-Finder and a U-Adcock Instrument. H. G. Hopkins and E. N. Bramley. (*IEE Radio Sect. Paper 1544.*) *Proc. IEE, Part III*, Sept., 1953, p. 263.

Radar

Interpretation of the Fluctuating Echo from Randomly Distributed Scatterers. I. J. S. Marshall and Walter Hitschfeld. **II.** P. R. Wallace. *Canadian J. Phys.*, Sept., 1953, pp. 962, 995. USAF-sponsored theoretical investigation at McGill University of random radar fluctuations to obtain greater reliability of interpretations, with analog computations.

Neutralizing Pentodes in Radar I-F Stages. Joseph C. Tellier. *Electronics*, Oct., 1953, p. 184. Circuit design procedure.

Transistorized (Airborne) Radar Scope Display Unit. Raymond S. Markowitz. *Electronics*, Oct., 1953, p. 182. Strength, miniaturization, and other factors.

Wave Propagation

The Calculation of the Path of a Radio-Ray in a Given Ionosphere. A. H. De-Voogt. *Proc. IRE*, Sept., 1953, p. 1183.

Diffraction of Electromagnetic Waves by an Aperture in a Large Screen. G. Bekefi. *J. Appl. Phys.*, Sept., 1953, p. 1123. Development of an approximate solution based on an evaluation of an inhomogeneous scalar boundary-value problem as part of a theoretical and experimental investigation of microwave propagation at the Eaton Electronics Research Lab., McGill University.

Series Expansions of Rays in Isotropic, Non-Homogeneous Media. Saul Gorn. *Quart. Appl. Math.*, Oct., 1953, p. 355. Analysis of air-to-air radio propagation as applied to high-accuracy distance measuring.

Study of the Ionospheric D-Region Using Partial Reflections. F. F. Gardner and J. L. Pawsey. *J. Atmos. & Terrestrial Phys.*, July, 1953. p. 321.

The Vector Wave Function Solution of the Diffraction of Electromagnetic Waves by Circular Disks and Apertures. I—Oblate Spheroidal Vector Wave Functions. II—The Diffraction Problems. Carson Flammer. *J. Appl. Phys.*, Sept., 1953, pp. 1218, 1224.

Equipment

Lifing of Aircraft Equipment. H. L. Stevens. *J. RAeS.*, Sept., 1953, p. 597.

Electric

Multiple Contact Resistance. William B. Kouwenhoven and Donald R. Hagner. *Welding J. Res. Suppl.*, Sept., 1953, p. 432-s. Experimental analysis of the phenomenon of contact resistance in high current, low impedance applications.

Power Equalizer Systems for Aircraft Alternators. J. A. Granath and A. K. Hawkes. *Elec. Eng.*, Oct., 1953, p. 893. Abridged. Use of analytical methods to predict operating conditions.

Sliding Contacts—A Review of the Literature. Frank Spayth and Stanton East. *Elec. Eng.*, Oct., 1953, p. 912. 43 refs.

Hydraulic & Pneumatic

Adventures in Extreme Temperature Hydraulics. George R. Keller. *SAE Natl. Aeronautic Meeting, New York, Apr. 20–24, 1953, Preprint 71.* 12 pp. Problems related to the "thermal barrier"; design and development of components and control systems.

The Development of High Temperature Hydraulic Fluids. J. C. Mosteller and John A. King. *SAE Natl. Aeronautic Meeting, New York, Apr. 20–24, 1953, Preprint 13.* 24 pp. Survey of USAF research investigations.

High-Temperature Problems Associated with Aircraft Hydraulic Systems. Frank C. Mittell. *SAE Natl. Aeronautic Meeting, New York, Apr. 20–24, 1953, Preprint 70.* 25 pp.

Pressure Surges in Hydraulic Circuits. Nils M. Sverdrup. *Prod. Eng.*, Sept., 1953, p. 161. Mathematical analysis of the pressure-wave problem; applications.

Remote Control of Double-Acting Pneumatic Cyclinders. Fred W. Hicks. *Prod. Eng.*, Sept., 1953, p. 170. Design of six basic circuits to solve complex air-control problems.

Flight Operating Problems

Hemispherical Bombing; Operations with the Aid of Flight-refuelling; an Analysis of Possibilities. C. H. Latimer-Needham. *Flight*, Sept. 11, 1953, p. 375.

Reduction of Aircraft Engine Noise Hazards. Emanuel S. Mendelson. *J. Av. Med.*, Aug., 1953, p. 340.

Prone or Supine? *Aeronautics*, Sept. 26, 1953, p. 90. Analysis of pilot attitude in high-speed flight, with a discussion of physiologic resistance to acceleration.

Ice Prevention & Removal

Evaporation of Drops of Liquid. J. K. Hardy. *Gt. Brit., ARC R&M 2805* (Mar., 1947), 1953. 9 pp. BIS, New York. $0.75. Experimental analysis of processes associated with icing conditions.

Impingement of Droplets in 90° Elbows with Potential Flow. Paul T. Hacker, Rinaldo J. Brun, and Bemrose Boyd. *U.S., NACA TN 2999*, Sept., 1953. 58 pp. 14 refs.

It's Done with Mirrors. Don Rogers and C. F. Matthews. *Jet Age*, Summer, 1953, p. 1. Icing tests on the Avro Canada C-100; description of the ice-protection system.

Flight Safety & Rescue

Contour Envelopes. I. T. Freer. *J. GAPAN*, Aug., 1953, p. 5. Determination of safety heights from topographical maps and charts; application to navigator's problems.

Tentative NFPA Standard on Aircraft Hangars. *NFPA 85-T*, June, 1953. 47 pp. Recommendations on the construction and fire protection of hangars and buildings.

Fuels & Lubricants

Bearings, Lubricants, and Lubrication; A Digest of 1952 Literature. J. C. Geniesse and H. A. Hartung. *Mech. Eng.*, Oct., 1953, p. 801. 124 refs.

Coefficient of Friction and Damage to Contact Area During the Early Stages of Fretting. I—Glass, Copper, or Steel Against Copper. Douglas Godfrey and John M. Bailey. *U.S., NACA TN 3011*, Sept., 1953. 23 pp.

Fuel for Jet Transports. A. R. Ogston *Esso Air World*, July–Aug., 1953, p. 7. Analysis of technical suitability of fuel for different types of engines.

A Comparison of Propellants and Working Fluids for Rocket Propulsion. Krafft A. Ehricke. *J. ARS*, Sept.–Oct., 1953, p. 287. Includes diagrams and tables of characteristics, performance, and operational data.

Vapor Pressures of Concentrated Nitric Acid Solutions in the Composition Range 83 to 97 percent Nitric Acid, 0 to 6 percent Nitrogen Dioxide, 0 to 15 percent Water, and in the Temperature Range 20° to 80°C. A. B. McKeown and Frank E. Belles. *U.S., NACA RM E53G08*, Sept. 17, 1953. 22 pp. 10 refs.

Instruments

Basic Instrumentation at NBS. *U.S., NBS Sum. Tech. Rep. 1813*, Sept., 1953. 10 pp. 13 refs. The NBS 4-year program to develop theoretical and experimental research apparatus.

An Electro-Mechanical Programme Controller. A. F. Watson and P. K. C. Wiggs. *J. Sci. Instr.*, Sept., 1953, p. 324. Application to problems of time recording and control.

General Theory and Operational Characteristics of the Gyrotron Angular Rate Tachometer. Roland E. Barnaby, John B. Chatterton, and Fred H. Gerring. *Aero. Eng. Rev.*, Nov., 1953, p. 31. Design details; applications.

A New Space Rate Sensing Instrument. Joseph Lyman. *Aero. Eng. Rev.*, Nov., 1953, p. 24. Qualitative analysis of operational and design principles of the Sperry Gyratron angular tachometer to secure a spatial reference signal source.

Studying Shock Waves with a Mach-Zehnder Interferometer. David Weimer. *The Frontier*, Sept., 1953, p. 4.

Saab's Coordinatograph; An Important Aid to Aircraft Design. K. Sjörgren and A. von Hausswolff. *Saab Sonics*, No. 19, 1953, p. 14.

Servo Systems for Performing Mathematical Operations. Ernest Wall. *Prod. Eng.*, Sept., 1953, p. 134. Design and performance analysis of characteristics, with basic circuits.

High Capacity Load Calibrating Devices; NBS Dynamometers for Calibrating Multimillion-Pound Testing Machines. *U.S., NBS Tech. News Bul.*, Sept., 1953, p. 137.

I—Some Applications of Strain Gages in Aeronautical Research. Ira H. Abbot. **II—Flight Test Applications of Strain Gages.** Walter K. Rickert. *NATO AGARD Memo. AG 2/MI*, 1953. 53 pp. In English and French.

Apparatus for Low Temperature Calorimetry. R. W. Hill. *J. Sci. Instr.*, Sept., 1953, p. 331. 10 refs. Design of the Cryostat to measure specific heats of solids over a continuous range of temperature.

A Method of Examining the Transverse Vibrations of Rods and Reeds. P. L. Kirby. *Brit. J. Appl. Phys.*, Sept., 1953, p. 279. Device to record and measure damping capacity at vibration frequencies from 10 to several hundred cycles per sec.

Pressure-Measuring Devices

Considerations Entering into the Selection of Probes for Pressure Measurement in Jet Engines. Clarence C. Gettelman and Lloyd N. Krause. *Instruments, ISA J.* sect., Sept., 1953, p. 1385.

Effect of Interaction Among Probes, Supports, Duct Walls and Jet Boundaries on Pressure Measurements in Ducts and Jets. Lloyd N. Krause and Clarence C. Gettelman. *Instruments, ISA J.* sect., Sept., 1953, p. 95.

High - Resolution Micromanometer. *U.S., NBS Tech. News Bul.*, Sept., 1953, p. 140. NBS-developed diaphragm-capacitance type.

Pressure Error Measurement using the Formation Method. K. C. Levon. *Gt. Brit., ARC CP 126*, 1953. 15 pp. BIS, New York. $0.75.

Techniques for Measuring and Controlling Vacuum. C. C. Roberts and W. W. O'Hara. *Prod. Eng.*, Sept., 1953, p. 190. Operating principles and performance characteristics of direct and inferential measuring gages for analysis of below-atmospheric pressures.

Recording Equipment

Apparatus for Automatically Recording the Absorption of Oxygen. J. C. E. Button and A. J. Davies. *J. Sci. Instr.*, Sept., 1953, p. 307. Application to the study of oils and other materials.

The Measurement of Acceleration Pulses With the Multifrequency Reed Gage. Henry Shapiro and D. E. Hudson. *J. Appl. Mech.*, Sept., 1953, p. 422.

A Spectrograph Unit for Use with the N.P.L. Gauge Interferometer. C. F. Bruce and V. R. Findlay. *J. Sci. Instr.*, Sept., 1953, p. 297. Combined with photographic recording apparatus.

Machine Elements

Cam Curvature. II—Reciprocating Inclined Flat-Faced Follower and Reciprocating Roller Follower. A. R. Holowenko and A. S. Hall. *Mach. Des.*, Sept., 1953, p. 162. Graphical methods for the exact calculation of different types of disc-cam systems.

Improving Gear Design with Shot Peening. John C. Straub. *Mach. Des.*, Sept., 1953, p. 294. Analysis of a process utilizing the impact of metallic shot to set up a surface layer of compressive stress; applications.

Assigning Tolerances for Maximum Economy. Eugene W. Pike and Thomas R. Silverberg. *Mach. Des.*, Sept., 1953, p. 139. Statistical procedure applied to mechanical linkage design.

An Exact Computing Linkage. Leo S. Packer. *Mach. Des.*, Sept., 1953, p. 171. A geometric analysis based on a single-link mechanism that generates higher-order plane curves by continuous motion.

Design of Helical and Leaf Springs for Minimum Weight. M. F. Spotts. *J. Appl. Mech.*, Sept., 1953, p. 435.

Designing Springs; How to Achieve Simplification and Reduce Costs. I—Compression Springs. Stanley L. Albright. *Mach. Des.*, Sept., 1953, p. 134.

Bearings

Bearings, Lubricants, and Lubrication; A Digest of 1952 Literature. J. C. Geniesse and H. A. Hartung. *Mech. Eng.*, Oct., 1953, p. 801. 124 refs.

Comparison of Operating Characteristics of Four Experimental and Two Conventional 75-Millimeter-Bore Cylindrical-Roller Bearings at High Speeds. William J. Anderson, E. Fred Macks, and Zolton N. Nemeth. *U.S., NACA TN 3001*, Sept., 1953. 27 pp. 13 refs.

Economy in Bearing Seal Space. E. P. Stahl. *Elec. Mfg.*, Oct., 1953, p. 108. Design and operational factors.

Effect of Bronze and Nodular Iron Cage Materials on Cage Slip and Other Performance Characteristics of 75-millimeter-Bore Cylindrical-Roller Bearings at DN Values to 2×10^6. William J. Anderson, E. Fred Macks, and Zolton N. Nemeth. *U.S., NACA TN 3002*, Sept., 1953. 24 pp. 13 refs.

Investigation of 75-Millimeter-Bore Deep-Groove Ball Bearings Under Radial Load at High Speeds. II—Oil Inlet Temperature, Viscosity, and Generalized Cooling Correlation. Zolton N. Nemeth, E. Fred Macks, and William J. Anderson. *U.S., NACA TN 3003*, Sept., 1953. 33 pp.

A Look at Hydrostatic Thrust Bearings. Frank R. Archibald. *Mach. Des.*, Sept., 1953, p. 170. Basic equations for flat-step, conical, and spherical types.

Rotating Discs & Shafts

Analytical Methods for Deriving Cam Profiles. Zbigniew Jania. *Tool Engr.*, Oct., 1953, p. 81.

The Calculation of Whirling Speeds of a System of Rotors Keyed to Co-axial Shafts. T. S. Wilson. *Gt. Brit., ARC R&M 2709* (May 24, 1948), 1953. 24 pp. BIS, New York. $1.50.

Unbalance Tolerances for Rotating Parts. K. Federn. (*Werkstatt und Betrieb*, May, 1953. p. 243.) *Engr. Dig.*, Sept., 1953, p. 339.

Materials

Ceramic-Metals for Component Design. Murray A. Schwartz. *Elec. Mfg.*, Oct., 1953, p. 144. Heat- and wear-resistant properties; applications and potentialities.

Selecting Materials to Meet Mechanical Design Requirements. J. R. Hunt. *Materials & Methods*, Sept., 1953, p. 102. Basic performance parameters, with a detailed alloy comparison table; derivations of formulas; economic factors.

Corrosion & Protective Coatings

After 280 Hr. at 1020 F. These Mild Steel Panels Show How Silicone-Aluminum Paints Stretch High-Temperature Life of Steel. A. E. Durkin and A. H. Horner. *Materials & Methods*, Sept., 1953, p. 114.

New Vinyl-Metal Sheet Resists Corrosion and Abrasion—Can be Formed. Philip O'Keefe. *Materials & Methods*, Sept., 1953, p. 94. Properties, advantages, and applications of the laminate.

Phenol Ether Resins—Versatile Raw Materials for the Coatings Industry. Donald E. Brody. *Organic Finishing*, Sept., 1953, p. 8.

Metals & Alloys

A Dictionary of Metallurgy. XX—Il–Ir. A. D. Merriman and J. S. Bowden. *Metal Treatment*, Sept., 1953, p. 413.

A Discussion on Fatigue. I—Fatigue. H. L. Cox. **II—Fatigue from the Metallurgist's Viewpoint.** E. R. Gadd. **III—Fatigue in Engine Design.** F. M. Owner. **IV—Fatigue in Aircraft Design.** B. E. Stephenson. **V—Summary of Discussions.** W. Tye. *J. RAeS.*, Sept., 1953, pp. 559, 565, 580, 584, 589. 81 refs. Held at University College, London, Mar. 27, 1953.

The Growth of Fatigue Cracks. A. K. Head. *Philos. Mag.* (*7th Ser.*), Sept., 1953, p. 925. Experimental and qualitative analysis of the mechanism of fatigue deformation and fracture of metals.

Nominal Compositions of Typical High Strength Heat Resisting Alloys and Limited Stress Rupture Data. (Materials Engineering File Facts No. 260.) J. B. Meierdirks, Jr. *Materials & Methods*, Sept., 1953, p. 139.

Radiation Characteristics of Metals. Joseph Poggie. *Prod. Eng.*, Sept., 1953, p. 205. Relative effects of surface texture and composition on emissivity of metals at high temperatures.

Recent Developments and Trends in Powder Metallurgy. H. W. Greenwood. *Metal Treatment*, Sept., 1953, p. 427.

Metals & Alloys, Ferrous

Fatigue Properties of Weld Metal L. A. Harris, R. B. Matthiesen, and N. M. Newmark. *Welding J. Res. Suppl.*, Sept., 1953, p. 441-s. Tests on specimens deposited with E7016 low-hydrogen electrodes and with E6010 high-hydrogen electrodes.

New Creep Resistant Ferritic Steels. David D. Howat. *Materials & Methods*, Sept., 1953, p. 87. British and European experience in the use of chromium steels modified 10—12% for high-temperature applications including gas turbines; advantages and limitations.

Studies of Continuous Phase Transformations with x-Rays. E. Gillam and D. G. Cole. *Philos. Mag.* (*7th Ser.*), Sept., 1953, p. 999. 14 refs. Experimental research on thermal and physical properties of EN24, EN26, and EN30B steels.

Study of Homogenisation of Steel by the Autoradiographic Method; Investigation of Dendritic Segregation of Phosphorus and Arsenic. A. Kohn. *Metal Treatment*, Sept., 1953, p. 405.

Metals & Alloys, Nonferrous

Compression Properties of Aluminium Alloys; Relation to Riveting and Upsetting. D. A. Barlow and A. W. Brace. *Metal Treatment*, Sept., 1953, p. 399.

Effect of Range of Stress on Fatigue of 76S-T61 Aluminum Alloy Under Combined Stresses Which Produce Yielding. W. N. Findley. *J. Appl. Mech.*, Sept., 1953, p. 365. 27 refs. Static tests for tension, compression, bending, and torsion; discussion of the role of anisotropy; mechanism of crack formation, mean stress, and maximum stress.

Influence of Striations on the Plastic Deformation of Single Crystals of Tin. K. A. Jackson and B. Chalmers. *Canadian J. Phys.*, Sept., 1953, p. 1017.

Thermal Cycles in the Arc Welding of ½-In. Titanium Plate. Appendix—Equipment and Instrumentation. E. F. Nippes, J. M. Gerken, B. W. Schaaf, and E. C. Nelson. *Welding J. Res. Suppl.*, Sept., 1953, pp. 461-s; 471-s. Investiga-

gation of the effect of cooling rates on the lowering of the transformation range; mechanical properties.

Nonmetallic Materials

Polystyrene Reinforced with Glass Fibers. H. G. Guy. *SPE J.*, Oct., 1953, p. 16. Analysis of physical properties; applications.

Reinforced Plastic Tubing. F. Robert Barnet and H. B. Atkinson, Jr. *SPE J.*, Oct., 1953, p. 22. NOL testing; applications.

Limitations of Synthetic Rubber Packings for High Temperature Application. E. L. Carlotta and E. M. Hobein. *SAE Natl. Aeronautic Meeting, New York, Apr. 20–24, 1953, Preprint 72.* 12 pp. Heat-resistant chemical characteristics and physical properties of various compounds; use in hydraulic and pneumatic systems.

Wood and Wood Base Materials. Kenneth Rose. *Materials & Methods*, Sept., 1953, p. 117. Classification of properties and engineering potentialities.

Testing

Determination of the Surface Stress by Means of Electroplating. H. Ōkubo. *J. Appl. Phys.*, Sept., 1953, p. 1130. New method of stress measurement using copper-plated test pieces by observing flecks on the surface produced by cyclic stress.

Direct Fatigue Tests with Tensile and Compressive Mean Stresses on 24S-T Aluminium Plain Specimens and Specimens Notched by a Drilled Hole. Gunnar Wallgren. *Sweden, Flygtekniska Försöksanstalten, FFA Meddelande NR 48*, 1953. 29 pp.

Free Surface Motion Induced by Shock Waves in Steel. William A. Allen. *J. Appl. Phys.*, Sept., 1953, p. 1180. Theoretical and experimental analysis of the shock deformation problem, with photographic data from recording microdensitometer readings.

Handling Equipment and Safety Containers for Use with Isotope γ-ray Sources for Industrial Radiography. D. R. Allen, H. S. Peiser, J. R. Rait. *Brit. J. Appl. Phys.*, Sept., 1953, p. 268. Application to testing of alloy steel castings.

A Method of Correcting for Initial Stresses in Frozen-Stress Observations. H. T. Jessop. *Brit. J. Appl. Phys.*, Sept., 1953, p. 281. Application to the solution of the problem of producing stress-free blocks of photoelastic materials.

Photometric Determination of Columbium, Tungsten, and Tantalum in Stainless Steels. Luther Ikenberry, J. Leo Martin, and W. J. Boyer. *Anal. Chem.*, Sept., 1953, p. 1340.

Some Applications of High-Power Ultrasonics in the Metal Industries. E. A. Neppiras. *Metal Treatment*, Sept., 1953, p. 391. 32 refs. Review of testing and other techniques.

Stress-Strain Relations, Uniqueness and Variational Theorems for Elastic-Plastic Materials with a Singular Yield Surface. W. T. Koiter. *Quart. Appl. Math.*, Oct., 1953, p. 350.

Mathematics

Alternating Method on Arbitrary Riemann Surfaces. Leo Sario. *Pacific J. Math.*, Sept., 1953, p. 631. 18 refs.

Approximate Solution of Simultaneous Equations by Means of Transformation of Variables. Applications to Aeronautical Problems. B. Langefors. *SAAB TN 7*, Oct. 15, 1952. 26 pp.

The Arithmetic of Field Equations. A. Thom. *Aero. Quart.*, Aug., 1953, p. 205. 13 refs. Details of an analytical method older than the approximate relaxation one used to solve equations of the Laplace and Poisson types.

The Location of the Roots of Polynomial Equations by the Repeated Evaluation of Linear Forms. L. Tasny-Tschiassny. *Quart. Appl. Math.*, Oct., 1953, p. 319.

A Method for Solving Third and Higher Order Nonlinear Differential Equations. Y. H. Ku. *J. Franklin Inst.*, Sept., 1953, p. 229.

A Method of General Linear Frames in Riemanian Geometry. I. Harley Flanders. *Pacific J. Math.*, Sept., 1953, p. 551.

On the Inversion of Continuant Matrices. W. J. Berger and Edward Saibel. *J. Franklin Inst.*, Sept., 1953. p. 249.

Orthogonal Harmonic Polynomials. P. R. Garabedian. *Pacific J. Math.*, Sept., 1953, p. 585. Derivation of formulas to solve such partial differential equations as:

$$\frac{\partial^2 f}{\partial \rho} + \frac{1}{\rho}\frac{\partial f}{\partial \rho} + \frac{\partial^2 f}{\partial z^2} = 0$$

used in the analysis of axially symmetric flow.

Plane Geometries from Convex Plates. Marlow Sholander. *Pacific J. Math.*, Sept., 1953, p. 667.

The Summation of Series Involving Roots of Transcendental Equations and Related Applications. M. R. Speigel. *J. Appl. Phys.*, Sept., 1953, p. 1103.

Approximate Solution of an Initial Value Problem by Generalized Cardinal Series. H. D. Brunk. *Quart. Appl. Math.*, Oct., 1953, p. 285.

Convexity Properties of Integral Means of Analytic Functions. H. Shniad. *Pacific J. Math.*, Sept., 1953, p. 657.

Legendre Functions of Fractional Order. Marion C. Gray. *Quart. Appl. Math.*, Oct., 1953, p. 311. Theoretical and experimental applications.

Discriminatory Analysis; Nonparametric Discrimination: Small Sample Performance. Evelyn Fix and J. L. Hodges, Jr. *USAF SAM Project 21-49-004 Rep. 11*, Aug., 1952. 43 pp. Analysis of an optimum statistical classification procedure dependent upon small sample distributions.

Distribution of Round-Off Errors for Running Averages. R. E. Greenwood and A. M. Gleason. *Pacific J. Math.*, Sept., 1953, p. 605.

The Negentropy Principle of Information. L. Brillouin. *J. Appl. Phys.*, Sept., 1953, p. 1152. Including discussion of distance, time, and space measurement.

Mechanics

Geometrical Methods in the Analysis of Ordinary Differential Equations; Introduction to Non-Linear Mechanics. J. Kestin and S. K. Zaremba. *Appl. Sci. Res., Sect. B*, No. 3, 1953, p. 149. 25 refs. Application to the study of vibrations, electrical circuits, and problems of fluid mechanics.

Meteorology

A Method for Forecasting Hailstone Size at the Earth's Surface. Ernest J. Fawbush and Robert C. Miller. *Bul. AMS*, June, 1953, p. 235. Three-year USAF experience and study.

A Proposed Modification of Hurricane Reconnaissance Procedures. Leon Sherman. *Bull. AMS*, June, 1953, p. 256. USN-USAF observations of wind fields and research on the location of the "hyperbolic point" of a storm.

Review of Methods of Long-Range Forecasting with Particular Reference to the British Isles. J. M. Stagg. *Meteorological Mag.*, Aug., 1953, p. 225.

Rocket Exploration of the Upper Atmosphere. Eric Burgess. *The Engr.*, Sept. 4, 1953, p. 302. High-altitude research activities; economic and other factors.

Some Statistical Results on the Phenomena Associated with Ionospheric Storms. D. W. G. Chappell, L. B. Hainsworth, and I. M. Moorat. *J. Atmos. & Terrestrial Phys.*, July, 1953, p. 301. 14 refs. Analysis of abnormalities in the height and ionization density of the F_2 layer in terms of the upper and lower frequency limits of radio communications.

Missiles

Aerodynamic Forces on a Cylinder for the Free Molecule Flow of a Nonuniform Gas. S. Bell and S. A. Schaaf. *J. ARS*, Sept.-Oct., 1953, p. 314. 13 refs.

The Definitions of the Angles of Incidence and of Sideslip. C. H. E. Warren. *Gt. Brit., ARC CP 124* (Aug., 1952), 1953. 11 pp. BIS, New York. $0.65. Application to theoretical and experimental missiles investigations.

The Determination of Skin Temperatures Attained in High Speed Flight. F. V. Davies and R. J. Monaghan. *Gt. Brit., ARC CP 123* (Feb., 1952), 1953. 65 pp. 14 refs. BIS, New York. $2.85. Calculation of the problem affecting missiles.

Navigation

Constant Compass Heading for Great Circle Navigation and the N-1 Compass System. LeRoy D. Allen. *Navigation*, Sept., 1953, p. 325.

Nautical and Statute Mile Controversy. Merrill Armour. *Navigation*, Sept., 1953, p. 333.

Requirements for Aeronautical Charts. E. R. McCarthy. *Navigation*, Sept., 1953, p. 322.

Photography

Special Camera Expedites Aircraft Projects. C. L. Pogorel. *Auto. Ind.*,

Sept. 15, 1953, p. 52. Design of equipment; Convair technique.

Versatile Photometric Goniometer. *U.S., NBS Tech. News Bul.*, Sept., 1953, p. 133. Apparatus used in NBS studies of aircraft and other lighting equipment.

Power Plants

British Aero-engines Today. *The Aeroplane*, Sept. 11, 1953, p. 375. Fifteen-page survey of characteristics and performance of 30 power plant designs, ranging from a 120 lb.-thrust pulse-jet to a 10,000–12,000 lb.-thrust axial-flow jet engine.

British Progress in Propulsion Since the War; A Survey of the Development of Gas Turbines, Piston Engines and Other Power Plants Since 1945. A. D. Baxter. *Aircraft Eng.*, Sept., 1953, p. 250. 13 refs. Design features and relative efficiency of the various types, with charts and diagrams.

Su Alcune Possibili Linee di Sviluppo del Motore Aeronautico (On Some Possible Development Trends of Aero Engines). Lorenzo Poggi. *L'Aerotecnica*, June, 1953, p. 199. In Italian. Analysis of thermopropulsion processes and potentialities of turbojet cycle modifications.

Jet & Turbine

Blading a New Science; The "How" and "Why" of Jet Engine Blades. F. H. Keast. *Jet Age*, Summer, 1953, p. 10.

An Experimental Single-stage Air-cooled Turbine. II—Research on the Performance of a Type of Internally Air-cooled Turbine Blade. D. G. Ainley. *Aircraft Eng.*, Sept., 1953, p. 269. Analysis includes charts and diagrams.

Metodo di Calcolo delle Caratteristiche dei Turbogetti e dei Turboelica—Espressioni Utili per Ricerche di Propulsione e Meccanica del Volo (A Method of Calculation of the Performance of Turbo-Jets and Turbo-Props—Some Useful Formulas for Studies on Propulsion and Flight Mechanics). Gas Are Santangelo. *L'Aerotecnica*, June, 1953, p. 204. In Italian.

Starting Jet Engines with Turbo-Compressor. O. H. Jacobson, and P. Volkmar. *Auto. Ind.*, Oct. 1, 1953, p. 50. Specifications of the AiResearch Model ATS 140 and the Turbomeca Palouste air turbine starters.

Techniques for Determining Thrust in Flight for Airplane Equipped with Afterburners. L. Stewart Rolls and C. Dewey Havill. *IAS Annual Summer Meeting, July 15–17, 1953, Los Angeles, Preprint 418.* 9 pp. Members, $0.35; Nonmembers, $0.75.

Rocket

The Evaluation of Competing Rocket Power Plant Components for Two-Stage Long Range Vehicles. A. L. Feldman. *J. ARS*, Sept.-Oct., 1953, p. 297.

High-Frequency Combustion Instability in Rocket Motor with Concentrated Combustion. Luigi Crocco and Sin-I Cheng. *J. ARS*, Sept.-Oct., 1953, p. 301.

The Instrumentation of Rocket Motor Test Beds. J. Venn. *J. Brit. Interplanetary Soc.*, Sept., 1953, p. 213. Basic test measurement requirements, with methods to determine pressure, temperature, flow rate, and time.

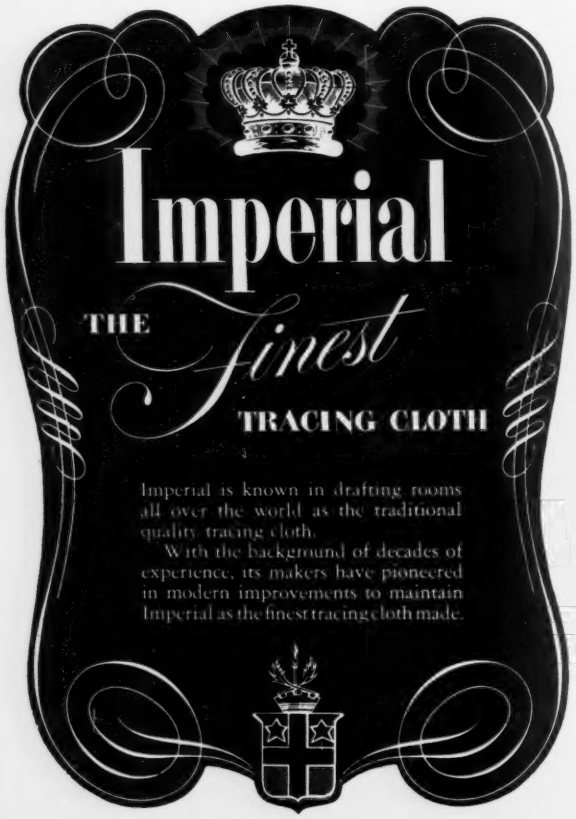
Television Monitors Rocket Engine Flame. Frank A. Friswold. *Electronics*, Oct., 1953, p. 187. NACA Propulsion research application; high-noise level, atmospheric corrosion, intensity of detail, and other factors; circuit details.

Production

New British Planes Reach Production Stage. W. F. Bradley. *Auto. Ind.*, Oct. 1, 1953, p. 60. Survey of developments.

Special SBAC Show Issue: British Aircraft Industry Number. *The Aeroplane*, Sept. 4, 1953. 351 pp., tables, charts, diagrams, cutaway drawings. Covers industrial development and research on conventional and experimental aircraft, engines, and components; 18 Directory Sections include alphabetical listings of manufacturers and distributors of services, materials, and finished aircraft, components, accessories, and specialized equipment.

Keeping Track of Projects with Control Boards. W. E. Elder. *Prod. Eng.*, Sept., 1953, p. 141. Bendix Aviation Corp. experience.


Imperial
THE Finest
TRACING CLOTH
Imperial is known in drafting rooms all over the world as the traditional quality tracing cloth.
With the background of decades of experience, its makers have pioneered in modern improvements to maintain Imperial as the finest tracing cloth made.

Over 85% of the torque wrenches used in industry are
STURTEVANT
TORQUE WRENCHES
Read by Sight Sound or Feel
• Permanently Accurate
• Practically Indestructible
• Faster—Easier to use
• Automatic Release
• All Capacities
in inch ounces
...inch pounds
...foot pounds
(All sizes from 0-6000 ft. lbs.)
STURTEVANT TORQUE MANUAL
Every manufacturer, design and production man should have this valuable data. Sent upon request.
P.A. STURTEVANT CO.
ADDISON QUALITY ILLINOIS

Bendix Builds a Better *cable clamp* the AN3057B

Inexpensive • Efficient • Versatile

The new Bendix AN approved AN3057B cable clamp is now available. Engineered by Bendix to the highest quality standards, this cable clamp offers major design improvements. The clamping action is radial and completely eliminates wire strain and chafing by holding the wire bundle firmly in rubber. This clamp will accommodate a wide range of wire bundle sizes, but an even greater range can be handled through the use of the Bendix AN3420A accessory telescoping sleeve.

The new AN3057B cable clamp will also waterproof multi-conductor rubber covered cable on the rear of a connector, or where moisture-proof entrance through a bulkhead or into an equipment box is required.

This versatile clamp is a product of the Scintilla Magneto Division of Bendix Aviation Corporation and is a companion AN accessory to the world famous Bendix Scinflex line of electrical connectors. Write our Sales Department for details.

Outstanding Features

- Neoprene gland.
- Centered clamping action.
- Increased close down.
- Positive grounding feature.
- Cadmium plated die-cast aluminum nut.
- Shorter over-all length.
- Waterproofs multi-conductor cable.
- Immediate delivery.

Bendix

SCINTILLA MAGNETO DIVISION of Bendix AVIATION CORPORATION
SIDNEY, NEW YORK

FACTORY BRANCH OFFICES: 117 E. Providencia Ave., Burbank, Calif. • 582 Market Street, San Francisco 4, California • Stephenson Bldg., 6560 Cass Ave., Detroit 2, Michigan • 615 Greenwood Ave., Jenkintown, Pa. • Brouwer Bldg., 176 W. Wisconsin Avenue, Milwaukee, Wisconsin. *EXPORT SALES:* Bendix International Division, 205 East 42nd St., New York 17, N. Y.

ALLIED RESEARCH ASSOCIATES
INCORPORATED

CONSULTING ENGINEERS

•

Specialists in
Aircraft and Guided Missiles
Structural Dynamics–Instrumentation

•

43 Leon Street, Boston 15, Mass.

Garrison 7-8170

When you write to manufacturers whose advertising appears in the **Aeronautical Engineering Review,** it will be of interest to the companies and of benefit to the Institute if you mention that you saw it in the **Aeronautical Engineering Review**

"MONOBALL" ®
SELF-ALIGNING BEARINGS

CHARACTERISTICS

ANALYSIS	RECOMMENDED
1. Stainless Stee Ba & Race	1. For types operating under high temp. (800—1200 degrees F.)
2. Chrome Molly Stee Ball & Race	2. For types operating under high radial ultimate loads (3000—893,000 lbs.).
3. Bronze Race & Chrome Molly Steel Ball	3. For types operating under normal loads with minimum friction requirements.

Thousands in use. Backed by years of service life. Wide variety of Plain Types in bore sizes 3/16" to 6" Dia. Rod end types in similar size range with externally or internally threaded shanks. Our Field Engineers welcome an opportunity of studying individual requirements and prescribing a type or types which will serve under your demanding conditions. Southwest can design special types to fit individual specifications. As a result of thorough study of different operating conditions, various steel alloys have been used to meet specific needs. New types have been developed, many as a result of specific requirements of our customers. Write or wire now for revised Engineering Manual describing complete line of "Monoball" Self-aligning Bearings and Rod Ends. Please address Dept. AER-53.

SOUTHWEST PRODUCTS CO.
1705 S. Mountain Ave. Duarte, Calif.

Quality Control as a Methods Improvement Function in Automotive and Aircraft Parts Manufacturing. E. F. Gibian. *Ind. Quality Control*, Sept., 1953, p. 22.

Metalworking

Design Considerations Associated With Large Aluminum Forgings. Chris W. Andrews. *Mech. Eng.*, Oct., 1953, p. 777. Douglas Aircraft Co. experience.

Designing Electroformed Parts. William H. Metzger, Jr., and Vernon A. Lamb. *Mach. Des.*, Sept., 1953, p. 124. Analysis of the electrodeposition process; advantages and limitations; applications.

Machining of High-Tensile-Strength Steel. F. M. Rayburn. *Mech. Eng.*, Oct., 1953, p. 794. Menasco Co. experience in aircraft landing gear manufacture.

Metal-Cutting Friction Coefficient Needs Reinterpretation. M. Kronenberg. *Tool Engr.*, Oct., 1953, p. 49.

Roll Forming; Simple Method for Designing Rolls. Elmer J. Vanderploeg. *Tool Engr.*, Oct., 1953, p. 59.

Shell Molding of Stainless Steel. Walter H. Dunn and Robert E. Day. *Prod. Eng.*, Sept., 1953, p. 129. Advantages, limitations, and possibilities with a comparison of other casting processes; design factors.

Vacuum Impregnation Makes Porosity-Free Castings. John H. Leary. *Materials & Methods*, Sept., 1953, p. 91. Analysis of procedure; economic factors; applications.

Arc Welding of Ferritic and Austenitic Nodular Cast Iron. J. Sohn, W. Boam, and H. Fisk. *Welding J.*, Sept., 1953, p. 823. Investigation of filler wires for inert arc welding as applied to stainless steel for jet engine parts; analysis of mechanical properties and effects of testing temperatures.

A Comparison of Shielding Mixtures for Gas-Shielded Arc Welding. J. W. Cunningham and H. C. Cook. *Welding J.*, Sept., 1953, p. 834. Research evaluation of gases as shielding media.

Load-Carrying Capacity of Fillet Weld Connections. F. Koenigsberger and H. W. Green. *Welding J.*, Sept., 1953, p. 859. Experimental analysis of joining rolled-angle sections and gusset plates for static and fatigue loads.

Low Temperature Stress Relieving of Mild Steel Welded Structures. L. E. Benson and S. J. Watson. *Trans. Inst. Welding*, Aug., 1953, p. 90.

Multitransformer Welding Presses. Jack Ogden. *Elec. Eng.*, Oct., 1953, p. 919. Analysis of equipment requirements and techniques; applications.

Porosity in the Welding of Carbon Steel. Glenn W. Oyler and Robert D. Stout. *Welding J. Res. Suppl.*, Sept., 1953, p. 454-s. Investigation of effects of current density, deoxidation practice of electrodes and base metal, and addition agents to the inert-gas atmosphere.

Russian Welding Practice. Carl A. Zapffe. *Welding J.*, Sept., 1953, p. 842. 24 refs. Sketch of research and technological developments.

Select the Right Method to Join Aluminum to Other Metals. Mike A. Miller. *Materials & Methods*, Sept., 1953, p. 96. Analysis of choice of materials, parts design, permissible joining temperatures, service requirements, and other factors.

The Welding of Certain Heat-Resisting Steels. J. A. McWilliam. *Trans. Inst. Welding*, Aug., 1953, p. 96. Comparison of metal-arc welding of a low-carbon 13 per cent chromium steel and a similar steel containing 0.16 per cent aluminum.

Propellers

Effects of Symmetric and Asymmetric Thrust Reversal on the Aerodynamic Characteristics of a Model of a Twin-Engine Airplane. Kenneth W. Goodson and John W. Draper. *U.S. NACA TN 2979*, Sept., 1953. 67 pp.

Linearized Potential Theory of Propeller Induction in a Compressible Flow. Robert E. Davidson. *U.S., NACA TN 2983*, Sept., 1953. 47 pp.

Subsonic Compressibility Corrections for Propellers and Helicopter Rotors. E. V. Laitone and Lawrence Talbot. *J. Aero. Sci.*, Oct., 1953, p. 683. University of California investigation based on the blade element theory; derivation of an approximate correction factor.

Reference Works

A Dictionary of Metallurgy. XX—II-Ir. A. D. Merriman and J. S. Bowden. *Metal Treatment*, Sept., 1953, p. 413.

The N.L.L. Card Catalogue of Aerodynamic Measurements. A. C. de Kock and A. I. van de Vooren. *Netherlands, NLL Rep. F. 125a*, June 20, 1953. 48 pp. Lists in appendixes include: symbols for forces, moments, and connected quantities; incompressible, subsonic, transonic, and supersonic flow characteristics; geometrical symbols; the figure code; and abstracted periodicals and reports.

Special SBAC Show Issue: British Aircraft Industry Number. *The Aeroplane*, Sept. 4, 1953. 351 pp., tables, charts, diagrams, cutaway drawings. Covers industrial development and research on conventional and experimental aircraft, engines, and components; 18 Directory Sections include alphabetical listings of manufacturers and distributors of services, materials, and finished aircraft, components, accessories, and specialized equipment.

Rotating Wing Aircraft

Design Considerations in the Kaman Servo-Controlled Intermeshing-Rotor Helicopter. Charles H. Kaman. *AHS New England Region Meeting, Windsor Locks, Conn., Feb. 9, 1953, Paper.* 6 pp.

Design Features of the XH-26 "Jet Jeep" Helicopter. Howard E. Roberts. *IAS Annual Summer Meeting, Los Angeles, July 15–17, 1953, Preprint 425.* 25 pp.

Some Handling Aspects Introduced by Increased Helicopter Requirements. W. R. Gellatly. *Amer. Helicopter*, Sept., 1953, p. 13.

Space Travel

L'Astronautica. Antonio Eula. *L'Aerotecnica*, June, 1953, p. 231. In Italian. Review of astronautical problems with possible solutions.

A Consideration of Space-Ship Shape. R. Cox Abel. *Aeronautics*, Sept. 26, 1953, p. 164. Structural principles in terms of launching and other requirements.

Navigational Calculations in Space Flight; Investigation of the Effect of the Precision of Astronomical Data. II—Planetary Orbital Velocities and Gravitational Fields and the Gravitational Field of the Sun. H. Ketchum. *J. Space Flight*, Sept., 1953, p. 1.

Structures

Determination of Optimum Dimensions for an Aircraft Fuselage Shell Considering Special Stiffness Criteria and Minimum weight. Pehr H. B. Schalin. *SAAB TN 8*, July 14, 1951. 19 pp. A solution based upon certain criteria for bending and torsional deflection distributions; numerical evaluations of structural configurations to show weight savings.

The Effect of Spanwise Rib-boom Stiffness on the Stress Distribution near a Wing Cut-out. E. H. Mansfield. *Gt. Brit., ARC R&M 2663* (Dec., 1947), 1953. 21 pp. BIS, New York. $1.40.

Experimental Investigation of the Stress Distribution in a Plastic Model of a 35° Swept Back Wing with Multi-Web Construction. Bryan R. Noton. *Sweden, Flygtekniska Försöksanstalten, FFA Meddelande NR 47*, 1953. 44 pp. 17 refs.

Structures—For High Speeds. Hall L. Hibbard and J. F. McBrearty. *Western Av.*, Oct., 1953, p. 22. Survey analysis of structural fatigue, rigidity, stress-strain, and other problems.

Beams & Columns

Determination of Stresses in Cemented Lap Joints. R. W. Cornell. *J. Appl. Mech.*, Sept., 1953, p. 355. Analytical investigation using the spring-beam analogy as an extension of the Goland-Reissner method.

The Flexural Centre or Centre of Shear. W. J. Duncan. *J. RAeS.*, Sept., 1953, p. 594. 14 refs. Review of investigations on elastic cantilever beams, with a formula covering the position of the "elastic centrum" in terms of the Prandtl torsional stress function.

A Generalised Approach to the Local Instability of Certain Thin-Walled Struts. A. H. Chilver. *Aero. Quart.*, Aug., 1953, p. 245. Solution of the elastic instability problem of the uniform compression of a thin-walled strut consisting of flat component plates.

Graphical Methods for Determining Beam Deflections. E. L. Richmond and R. H. Feng. *Mach. Des.*, Sept., 1953, p. 177. Analytical techniques, with diagrams.

Graphical-Numerical Solution of Problems of Saint-Venant Torsion and Bending. B. A. Boley. *J. Appl. Mech.*, Sept., 1953, p. 321. Stress-strain analysis of beams of arbitary cross section.

An Improved Electrical Analogy for the Analysis of Beams in Bending. W. T. Russell and R. H. MacNeal. *J. Appl. Mech.*, Sept., 1953, p. 349. 13 refs. Analogy for the solution of static-load, vibration, and transient-load problems.

An Iterative Solution to the Effects of Concentrated Loads Applied to Long Rectangular Beams. C. A. M. Gray. *Quart. Appl. Math.*, Oct., 1953, p. 263.

Large Deflections of a Cantilever Beam with Uniformly Distributed Load. F. Virginia Rohde. *Quart. Appl. Math.*, Oct., 1953, p. 337.

Note on the Stabilisation of Long Struts by an Elastic Medium. W. J. Goodey. *Aero. Quart.*, Aug., 1953, p. 279.

Elasticity & Plasticity

Calculation of Elastic Displacements From Photoelastic Curves. H. Poritsky and R. P. Jerrard. *J. Appl. Mech.*, Sept., 1953, p. 375.

Elastic Spheres in Contact Under Varying Oblique Forces. R. D. Mindlin and H. Deresiewicz. *J. Appl. Mech.*, Sept., 1953, p. 327. ONR-supported analytical investigation.

An Experimental Study of the Propagation of Transient Longitudinal Deformations in Elastoplastic Media. E. J. Sternglass and D. A. Stuart. *J. Appl. Mech.*, Sept., 1953, p. 427. Theoretical analysis of longitudinal plastic pulses in prestrained bars to test the validity of the Donnell-Taylor-von Kármán theory.

On the Use of Singular Yield Conditions and Associated Flow Rules. William Prager. *J. Appl. Mech.*, Sept., 1953, p. 317. Simplifications resulting in the mathematical analysis of plane plastic-stress problems.

The Principle of Complementary Energy in Nonlinear Elasticity Theory. Henry L. Langhaar. *J. Franklin Inst.*, Sept., 1953, p. 255.

Remarks on Combined Bending and Twisting of Thin Tubes in the Plastic Range. E. T. Onat and R. T. Shield. *J. Appl. Mech.*, Sept., 1953, p. 345. Influence of the loading program on the agreement between the prediction of the Hencky and the Prandtl-Reuss stress-strain relations for a perfectly plastic material.

Wave Propagation in Finite Rods of Viscoelastic Material. E. H. Lee and I. Kanter. *J. Appl. Phys.*, Sept., 1953, p. 1115. Stress analysis under rapid loading conditions of rods of a Maxwell material subjected to axial stresses.

Plates

The Diffusion of Load into a Panel Bounded by Constant Stress Booms and a Transverse Beam. E. H. Mansfield. *Gt. Brit., ARC R&M 2729* (Aug., 1948), 1953. 12 pp. BIS, New York. $0.90. Theoretical investigation, with curves, to determine the peak shear stress near the boom, the variation of this stress along the length of the panel, the proportion of load transferred by the beam, and the bending moment at the ends of the beam.

The Diffusion of Load into a Semi-infinite Sheet. I, II. E. H. Mansfield. *Gt. Brit. ARC R&M 2670* (June, 1948), 1953. 61 pp. 18 refs. BIS, New York. $3.75.

A Method of Estimating the Compressive Strength of Optimum Sheet-Stiffener Panels for Arbitrary Material Properties, Skin Thickness, and Stiffener Shapes. W. R. Micks. *J. Aero. Sci.*, Oct., 1953, p. 705.

Note on Rectangular Plates: Deflection Under Pyramidal Load. Wilhelm Ornstein. *Quart. Appl. Math.*, Oct., 1953, p. 339. An evaluative procedure using the Euler-Fourier analytic method.

Vibrazioni di Lastre Svergolate a Sbalzo (Vibrations of Twisted Cantilever Plates). Ettore Funaioli. *L'Aerotecnica*, June, 1953, p. 220. In Italian. Approximation by the energy method of the frequencies and modes of vibration.

Testing

Fatigue Life of Thick-Skinned Tension Joints. Edward W. Thrall, Jr. *Aero. Eng. Rev.*, Nov., 1953, p. 37. Results of fatique strength tests on 12 different tension splices for the development of structural designs in terms of operational requirements.

Seven Methods for Solving Structural Test Problems. Warren W. Bradley. *Prod. Eng.*, Sept., 1953, p. 172. Design of equipment and procedures used in airframe and missiles testing.

Tension Pads for Structural Testing at Convair; Details of the Method of Application of Rubber Tension Pads to Distribute Test Loads. A. R. Vollmecke. *Aircraft Eng.*, Sept., 1953, p. 286.

Thermodynamics

Effect of Pressure on the Smoking Tendency of Diffusion Flames. Rose L. Schalla and Glen E. McDonald. *U.S., NACA RM E53E05*, Sept. 17, 1953. 13 pp.

Theoretical Aspects of Flame Stabilization; An Approximate Graphical Method for the Flame Speed of Mixed Gases. D. B. Spalding. *Aircraft Eng.*, Sept., 1953, p. 264.

Modified Sturm-Liouville Systems. W. F. Bauer. *Quart. Appl. Math.*, Oct., 1953, p. 273. Mathematical analysis of the heat-conduction problem.

The Neumann Problem for the Heat Equation. W. Fulks. *Pacific J. Math.*, Sept., 1953, p. 567. ONR-sponsored studies.

Thermal Conductivity of Gases at Atmospheric Pressure. John M. Lenoir. *U. Ark. Eng. Exp. Sta. Bul. 18*, Aug., 1953. 48 pp. 81 refs. A survey of the literature; development of an accurate and rapid method to compute thermal conductivities of binary and polycomponent mixtures.

Thermodynamic Equations of State. Newman A. Hall. *Appl. Mech. Rev.*, Oct., 1953, p. 441. 36 refs. Review of the literature.

The Thermodynamics of Critical Phenomena in Gases. J. F. Lee. *J. Franklin Inst.*, Sept., 1953, p. 245. 16 refs. Derivation of a determinate expression for the sonic velocity at the critical point to permit a direct solution for the constant volume specific heat as a function of the critical values of temperature, specific volume, sonic velocity, and the Joule-Thomson coefficient.

Wind Tunnels & Research Facilities

High-Altitude and Speed Propulsion Wind Tunnel At the Arnold Engineering Development Center, Tullahoma, Tenn. F. L. Wattendorf, J. Noyes, and A. I. Ponomareff. *Mech. Eng.*, Oct., 1953, p. 789.

Notes on the Technique Employed at the R.A.E. in Low-Speed Wind-Tunnel Tests in the Period 1939–1945. F. B. Bradfield. *Gt. Brit., ARC R&M 2556* (Oct., 1947), 1952. 71 pp. 59 refs. BIS, New York. $4.50.

The Royal Aircraft Establishment 4 ft × 3 ft Experimental Low Turbulence Wind Tunnel. I—General Flow Characteristics. H. B. Squire and K. G. Winter. *Gt. Brit., ARC R&M 2690* (Feb., 1948), 1953. 28 pp. BIS, New York. $1.70.

A Steady-Flow Aeroelastic Study by Electrical Analogy. Robert H. Scanlan. *J. Aero. Sci.*, Oct., 1953, p. 691. The Malavard and Duquenne "lifting surface calculator" electrical tank as applied to research investigations.

The Toepler Schlieren Apparatus. D. W. Holder and R. J. North. *Gt. Brit., ARC R&M 2780* (Apr., 1950), 1953. 13 pp. BIS, New York. $1.00. Methods to satisfy wind-tunnel observation requirements; characteristics and applications of the shadowgraph-optical systems.

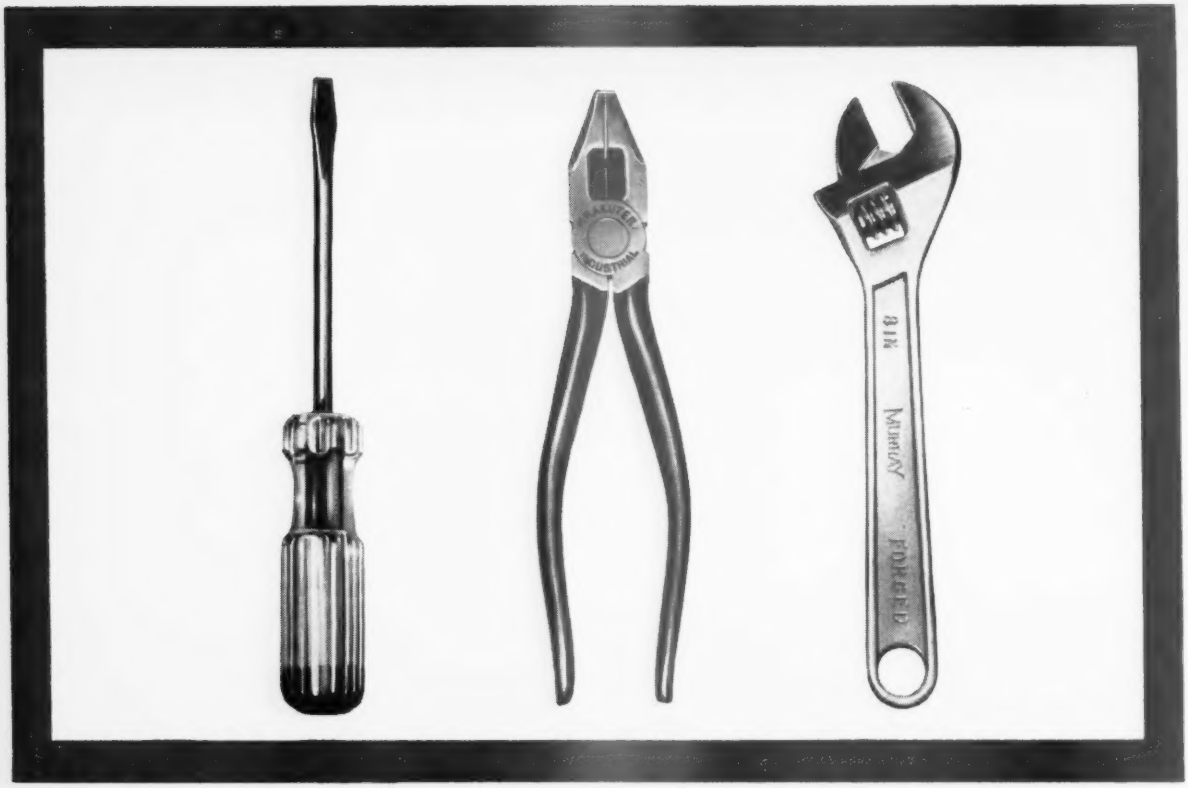
Using Models in Design. *Prod. Eng.*, Sept., 1953, p. 178. Applications include dimensional-similitude studies and developmental research on missiles and turbine engines.

A Wave-Height Analyser. M. J. Wilkie and R. F. King. *J. Sci. Instr.*, Sept., 1953, p. 311. The British Hydraulics Research Board's laboratory apparatus to determine significant wave heights; instrumentation and operational details.

Changes of Address

Since the Post Office Department does not as a rule forward magazines to forwarding addresses, it is important that the Institute be notified of changes in address 30 days in advance of publishing date to ensure receipt of every issue of the *Journal and Review*.

Notices should be printed legibly and sent directly to the Institute of the Aeronautical Sciences, Inc., 2 East 64th Street, New York 21, N.Y.



This is all you need to install
AVIEN'S TWO-UNIT FUEL GAGE

You need no field calibration, no complicated data, and no "experts" to install this simplified system.

When it's time to install Avien's Two-Unit Fuel Gage, all you will require are simple tools.

You won't need calibration instruments, complex field data, or specially trained personnel. The Avien gage will have been precalibrated for your aircraft, so installation becomes as simple as "plug-in, plug-out."

This quick and easy installation avoids costly, time-consuming calibration on the flight-line.

You will also find Avien's Two-Unit Gage an advantage for replacement and repair. You can keep it in regular stock, ready for immediate use.

This ease of installation is just one of the factors which have made Avien's Two-Unit Gage the most talked-about system in the industry.

Because the system is reduced to a sensing unit and indicating unit, it weighs 50% less than previous three-unit systems. Fewer wires and connectors are needed. 158 separate parts are eliminated. Maintenance problems are brought to the minimum.

And it costs less.

With the industry's need for smaller units – and with the industry's problem of smaller budgets – the Avien Two-Unit Fuel Gage arrives at the right moment.

Every month, Avien produces over ten thousand major instrument components for the aviation industry.

If you haven't yet inquired about the Two-Unit Gage, right now is the time to do so.

Avien

AVIATION ENGINEERING DIVISION
AVIEN-KNICKERBOCKER, INC.
58-15 NORTHERN BOULEVARD, WOODSIDE, L. I., N. Y.

Aeronautical Reviews — BOOKS

Human Factors in Air Transportation

By Ross A. McFarland. New York, McGraw-Hill Book Company, Inc., 1953. 830 pp., figs. $13.

The history of engineering is closely linked with man's desire to work less, travel faster, live in a healthier atmosphere, and, in general, to raise his standard of living and to provide himself with leisure for the pursuit of many interests not connected with making a living. In the last fifty years engineers and scientists have provided the human race with an array of equipment undreamed of by the two generations that preceded us. In our unbounded enthusiasm for technical perfection and efficiency, it has frequently happened that the machine has grown to a system of such complexity that the human body cannot take advantage of it.

Engineers and physicists are rarely trained to take cognizance of the limitations of the human machine and are anxious to know what they can do to build equipment that will not exceed human capabilities and endurance. Over a period of 25 years, with three books and many papers to his credit, Dr. Ross McFarland has dedicated his professional life to bridging the gaps between psychology, physiology, and engineering. He has been outstandingly successful in this task, and most modern airplanes show the influence of his teachings.

The present volume deals with all aspects of the human factor in air transportation and is a magnificent review of all that is known on this subject. The book starts with a statement of the problems involved in airline operation and a summary of regulations governing global air transport. Statistics are adduced showing that, as a result of the recognition of human failings and corrective measures taken by the major airlines, the safety of airlines has steadily increased.

Treated next is selection and training of flight personnel. Such recent precepts as psychological and psychiatric evaluation of airmen are given prominence, and, while in many instances the engineer will not completely understand the purely medical aspects of this exposition, it will give him warning that he should consult with specialists in selecting proper flight personnel. Similar advice is proffered concerning nonflight personnel such as air crews and airport attendants. The author shows how to select and place such personnel with due regard to personality factors. Next he takes up the health and safety of the ground and in-flight crews and in this connection gives a comprehensive review of the industrial safety movement in the United States.

A very interesting chapter describes the work and results accomplished in developing rescue and survival procedures in case of both military and civilian accidents.

One would not expect that sanitation, which is taken for granted in the western world, is a major problem in global air transport. In addition to the effect on passengers subjected to rapid change of countries with different sanitary standards, great care has to be exercised to prevent plant and animal diseases reaching other countries as established quarantine methods are incompatible with six-mile-a-minute speeds. The service problems pertaining to healthy and sick passengers are also discussed. The last chapter deals with health and medical services in air transportation.

In addition to its textual value, the book is extremely well written, so that the reader will derive both pleasure and benefit from it.

Dr. McFarland provides extensive statistical information. It is one of the few books known to the reviewer which in addition to the statistics gives also the method of obtaining them and the mathematical formulas for deriving the averages, thus forestalling any imputation of guesswork. This book should be read by every executive of an air line and by most project engineers having to do with air transportation. It is also highly recommended to the managers of other forms of transportation, as it will show them that the air lines base their development on scientific fact and make every effort to ensure the safety and satisfaction of the passenger.

In fine, this reviewer agrees with General Simmons who wrote the very able introduction to this volume and gave his appraisal in these words: "Dr. McFarland's painstaking research, creative thought and practical recommendations in the field of aviation make this work a valuable contribution to our knowledge of human problems in this mechanized age of air power."

DR. STEPHEN J. ZAND
Expert Consultant
Research and Development Board
Washington, D.C.

Book Notes

AERODYNAMICS

Mechanics of Flight. A. C. Kermode. 6th Ed. (An Introduction to Aeronautical Engineering, Vol. 1.) London, Sir Isaac Pitman & Sons, Ltd.; New York, The British Book Centre, Inc., 1953. 372 pp., illus., diagrs., figs. $4.50.

In this edition, the text has been heavily revised to bring it up to date, and chapters on mechanics and high-speed flight have been added. The original chapter on propellers has been amended to include the principles of jet and rocket propulsion. Not only have the numerical examples been brought up to date in line with the scope of the book itself, but new ones have been added.

Contents: Chapter I, Mechanics. Chapter II, Air and Airflow—Air Resistance. Chapter III, Aerofoils—Lift and Drag. Chapter IV, Thrust. Chapter V, Level Flight. Chapter VI, Gliding and Landing. Chapter VII, Performance. Chapter VIII, Manoeuvres. Chapter IX, Stability and Control. Chapter X, High-Speed Flight. Chapter XI, The Test Flight. Appendix 1, Aerofoil Data. Appendix 2, Units and Dimensions. Appendix 3, Scale Effect. Appendix 4, General Questions. Appendix 5, Numerical Questions. Appendix 6, Answers to Numerical Questions. Index.

For Information on IAS Library Service Facilities, see page 287

Statements and opinions expressed in Book Reviews are to be understood as individual expressions and not necessarily those of the Institute.

DIRECTORIES

The Aeroplane Directory of British Aviation; Incorporating Who's Who in British Aviation. Compiled by the Staff of *The Aeroplane*. 1953 Edition. London, Temple Press Limited, 1953. 540 pp.

A complete guide to aviation throughout the British Commonwealth—its air forces, ministries, organizations, air lines, industries, flying clubs, and airports—together with a biographical section containing over 1,550 entries.

ELECTRONICS

Principles of Transistor Circuits. Edited by Richard F. Shea. New York, John Wiley & Sons, Inc., 1953. 535 pp., diagrs., figs. $11.

The purpose of the present book is to gather under one cover a large portion of the volume of material that has been accumulated on the subject of transistor circuits. The book is aimed at graduate students and practicing engineers alike. Written by specialists in each field of application, it provides basic theory plus an elaboration of various techniques employed.

In order to make the book applicable to as many of these devices as possible, the authors used a general treatment built around generalized equivalent circuits which can be used conveniently to represent the great majority of transistors. After a brief introduction, the book is divided into three parts covering low-frequency, high-frequency, and large-signal, nonlinear applications. In each section the same general organization is followed: presentation and analysis of equivalent circuits, analysis of the mathematical relationships, and development of applicable circuits. Problems and an extensive bibliography are included. The authors are members of the engineering staff of the Electronics Laboratory, General Electric Company; the editor is Supervisor of the Semiconductor Applications Unit.

FLIGHT SAFETY

Résumé of U.S. Air Carrier Accidents Calendar Year 1952. Washington, D.C., Bureau of Safety Investigation, Civil Aeronautics Board, May 15, 1953. 27 pp.

MATERIALS

Ferrous Analysis; Modern Practice and Theory. E. C. Pigott. 2nd Ed., Revised. New York, John Wiley & Sons Inc., 1953. 690 pp., illus., figs. $12.50.

As in the previous edition, the aim has been to provide practical methods that fall within the scope of the average laboratory and are reliably selective and accurate, rapid and economical, and of general application. Processes of very limited application have not been treated. A development is the expansion of qualitative portions of the book. Metal surface spot-testing is one of the topics that are new features of the 31 constituents considered, a descriptive bibliography is given of ferrous-analysis research contributed throughout the world since 1930. The book is designed to be suitable as a work of reference for both the practicing analyst and the advanced student.

Elements of Heat Treatment. George M. Enos and William E. Fontaine. New York, John Wiley & Sons, Inc., 1953. 286 pp., illus., diagrs., figs. $5.00.

Written in simple language, *Elements of Heat Treatment* provides a grounding in the basic principles governing the application of heat to alter the mechanical properties of metals. The authors define the major heat-treatment processes—annealing, hardening, tempering, and normalizing—and show how each process is used to get the metal characteristics needed for a specific job. Background information on the properties of metals and alloys is presented in order to develop the reader's appreciation of the changes wrought by heat treatment. Casting, forging, rolling, welding, machining, and other processes related directly or indirectly to heat treatment are briefly discussed.

MATHEMATICS

An Introduction to Relaxation Methods. F. S. Shaw. New York Dover Publications, Inc., 1953. 396 pp., figs. $5.50.

This is a detailed guide for solving problems arising in fluid mechanics, the design of electrical networks and machinery, forces in structural frameworks, stress distribution and buckling, electron optics, chemistry, physics, and many other fields. Emphasis has been placed on the different types of equations rather than the problems of any specific subject. Numerical techniques are made clear by numerous step by step diagrams and by detailed examples. Special tables have been included for dealing with problems involving awkwardly shaped boundaries. The author is Associate Professor, Department of Aeronautics and Applied Mechanics, Polytechnic Institute of Brooklyn.

Contents: Introduction. Chapter I, Linear Algebraic Simultaneous Equations. Chapter II, Finite-Difference Approximations. Chapter III, Linear Ordinary Differential Equations. Chapter IV, Second Order Linear Partial Differential Equations. Chapter V, Second Order Linear Partial Differential Equations (Continued). Chapter VI, Second Order Linear Partial Differential Equations (Concluded). Chapter VII, Fourth Order Linear Partial Differential Equations. Chapter VIII, Eigenvalue Problems. Chapter IX, Free Surface Problems, Integral Equations, Accuracy, Non-Dimensional Treatment. Tables for Computing Irregular Star First and Second Derivatives. Irregular Star Coefficients for Second Order Equations. Irregular Star Coefficients for Fourth Order Equations. Bibliography of Papers, etc., Dealing with Relaxation Methods. Name Index. Subject Index.

PHYSICS

Mathematical Physics. Donald H. Menzel. New York, Prentice-Hall, Inc., 1953. 412 pp., diagrs. $11.35.

This volume, although primarily concerned with classical physics, specially emphasizes those topics closely related to modern phases, in either technique or subject matter. Several topics seldom presented—e.g., electron theory or general relativity—appear in considerable detail, because an understanding of them is increasingly vital to the student of atomic physics. The book has been designed for use in junior, senior, or graduate courses in mathematical physics. The student is expected to possess a good working knowledge of differential and integral calculus. Some prior experience with differential equations is desirable, though not absolutely necessary. All other phases of mathematics, function theory, vectors, matrices, dyadics, tensors, partial differential equations, etc., flow directly from the physics during the presentation of the various subjects. Such topics as existence theorems, convergence, and high degree of mathematical rigor do not receive special emphasis because they chiefly concern the pure mathematician.

Contents: Part 1, Physical Dimensions and Fundamental Units. Part 2, Mechanics and Dynamics. Part 3, Waves and Vibrations. Part 4, Classical Electromagnetic Theory. Part 5, Relativity. Index.

Microwave Spectroscopy. Walter Gordy, William V. Smith, and Ralph F. Trambarulo. New New York, John Wiley & Sons, Inc., 1953. 446 pp. illus., diagrs., figs. $8.00.

By summarizing the information obtained to date, this volume aims at providing an inclusive source work for microwave spectroscopists, chemists, physicists, and other scientists in the field. The authors also undertake to facilitate the analysis and interpretation of this accumulated data through conveniently arranged formulas and numerical tables. In approaching their final objective, they familiarize the beginner with the instruments and experimental methods, giving the theory involved in the detection of microwave absorption lines with detailed descriptions of significant spectrographic components. Supplementing their discussions with extensive bibliographies, the authors deal with instruments and experimental methods, microwave spectra of gases, Stark and Zeeman effects, and shapes and intensities of absorption lines of gases. They continue with spectra of solids, nuclear properties, electrical properties of molecules, molecular structures, and applications in other fields. Professor of Physics at Duke University, Walter Gordy is Director of the Microwave and Radio-frequency Laboratory there. William V. Smith is Professor of Physics and Chairman of the Department at the University of Delaware, and Ralph F. Trambarulo is Assistant Professor of Physics at The Pennsylvania State College.

Attention Members!

All members of the Institute are invited to submit material concerning their activities for publication in the "News of Members" columns of the *Aeronautical Engineering Review*. Responsibility for new developments, awards or honors received, and appointments to new or additional positions are some of the items that your editors believe are of interest to other IAS members. A brief letter or postal card giving exact details will be sufficient. Photographs accompanying news items will be welcomed and will be used where practicable.

Items will be considered on the basis of their timeliness and general interest. Correspondence should be addressed to the News Editor, *Aeronautical Engineering Review*, 2 East 64th Street, New York 21, N.Y.

Personnel Opportunities

This section is for the use of individual members of the Institute seeking new connections and organizations offering employment to Aeronautical specialists. Any member or organization may have requirements listed without charge by writing to the Secretary of the Institute.

Wanted

Engineers, Technologists, Physicists, Physiologists, Metallurgists—The Navy Air Material Center located at the U.S. Naval Base at the extreme south end of Broad Street in Philadelphia, Pa., has vacancies in the above positions for qualified eligibles. These vacancies are at grade GS-5 to GS-12 level with salary ranging from $3,410 to $7,040 per annum. The Naval Air Material Center (the Air Center is divided into three major branches: the Naval Aircraft Factory, the Naval Air Experimental Station, and the Naval Auxiliary Air Station) is engaged in research (applied), development, manufacture, modification, test evaluation, and overhaul of aircraft, aircraft components, and aeronautical materials, including launching and arresting devices. This activity has the job of finding the answers to a never-ending series of problems involving the whole field of aeronautical sciences. Interested persons should file an Application for Federal Employment, Standard Form 57, with the Industrial Relations Department, Naval Air Material Center, Naval Base, Philadelphia 12, Pa. Applications may be obtained from the Industrial Relations Department, Naval Air Material Center, or at any first- or second-class Post Office or from any Civil Service Regional Office.

The number preceding the notice represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

Assistant Professor—To teach airplane design, aircraft structures, and related subjects in the Aeronautical Option in Mechanical Engineering Department. Applicant should have Master's Degree or equivalent experience in aeronautical field. New building with excellent teaching facilities and opportunity for research. Applications should be sent to Prof. Robert M. Pinkerton, Mechanical Engineering Department, North Carolina State College, Raleigh, N.C.

532. Research Engineer—Recently organized Research and Development Division of medium-size aircraft components corporation in Ohio requires the services of senior graduate research engineer for new product analysis. Applicant should be intimately acquainted with heavier type of production machine tool equipment and have extensive experience in the aircraft or automotive fields. Salary commensurate with experience.

530. Design Engineers, Aerodynamicists—Minneapolis firm has openings for experienced aircraft structural and instrument designers. Degree not required if strong experience record is demonstrated. Minimum 5 years' experience required in responsible work. Aerodynamicists needed for subsonic and supersonic theory and applied design. Degree and minimum 2 years' experience required in this field. Opportunity for graduate work at near-by university for qualified applicants.

STRESS ANALYSTS

with actual aircraft stress experience

Also AIRCRAFT ENGINEERS AND DESIGNERS

Here's an opportunity to work in one of the most interesting and fastest-growing segments of the aviation field—

HELICOPTERS

Sikorsky Aircraft, foremost designer, developer and manufacturer of helicopters, is increasing its production of the latest type, combat-proved helicopters and is expanding its research and development program.

Here's your chance to work with the top men in your profession—men who made the first practical helicopter.

You'll Find at Sikorsky Aircraft

- a company with large and important orders
- an engineering staff of exceptionally high calibre
- unduplicated research and testing facilities
- a respect for and interest in new ideas

You'll Enjoy These Advantages

- excellent salary
- cost-of-living adjustments
- good chance for advancement
- many insurance benefits, including a retirement income plan

Moving Expense Allowance

Send resume to E. H. TUTTLE

SIKORSKY AIRCRAFT

Division of United Aircraft Corporation

Bridgeport 1, Conn.

Available

542. Structures Engineer—B.C.E., 13 years' experience. Stress analysis, design, test, research, and development. Aircraft, missiles, high-temperature pressure vessels, and nuclear power plants (3 years). Desires position in nuclear engineering.

541. Aeronautical Engineer—M.S. in Aeronautical Engineering. Age 27; 2½ years' experience in aerodynamics in a major North American aircraft firm. Desires design or research engineer's position in aerodynamics (stability and control) or aeroelasticity. Detailed résumé furnished on request.

540. Aviation Psychologist—Administrator. Age 27. B.A.-M.A. (pending). Experience as a research psychologist in aviation and administrator in flight safety work. Extensive experience in initiating and conducting field work. Air Force experience. Publications on military aviation. Desires position of responsibility in administration or design of flight safety activity. Willing to relocate.

539. Executive Engineer—Ten years of broad administrative experience in supervising engineering and production in the aircraft industry. Nineteen years' total experience, covering all phases of research, design, tooling, and scheduling. Desires position as executive engineer or administrative engineer.

537. Aeronautical Engineer—M. in Ae.E. Age 29; 3½ years' experience on aircraft and 5 years' experience on missiles, including structural design, flight and ground testing, and many phases of production management. Desires a responsible position in production management in a medium-size concern with opportunity for advancement. State nature of position.

536. Engineer—M.E., Ae.E., Professional Engineer, Age 37. Ten years' diversified aeronautical stress engineering experience, including 2 years on helicopters. Some additional electromechanical stress analysis experience, including gear and actuator design. Desires position offering responsibility and opportunity for advancement. Available December or January 1. Complete résumé on request. Please indicate nature and salary range of positions available.

535. Aero- and Hydrodynamicist—Dr. of Engineering with 22 years' experience in aerodynamic and hydrodynamic research; wind-tunnel, flight, and hydrodynamic testing; and de-

DESIGNERS, ENGINEERS...

The SKY'S no longer the LIMIT at Martin

Today the men at Martin are building the spaceborne systems of tomorrow. Every rocket that screams skyward brings back more information of outer space. Every day brings man closer to conquering the heavens. It's thrilling work — reaching beyond the sky.

And the sky is no longer the limit on OPPORTUNITY *at Martin. Young men are now in top positions at Martin. We need more young men for exciting jobs—creative engineers. We need:*

AERODYNAMICS ENGINEER
●
VIBRATION ANALYSIS ENGINEER
●
STRUCTURES ENGINEER
●
FLIGHT SIMULATION ENGINEER
●
DESIGN ANALYST
●
NEW DESIGN SPECIALIST
●
PROJECT ENGINEER
●

Martin offers modern engineering facilities and liberal benefits, including company paid pension plan. Liberal travel and moving allowances. Housing readily available.

WRITE NOW TO: J. J. Holley, Professional Employment, Dept. E-12, The Glenn L. Martin Co., Baltimore 3, Md. *Include confidential resume with full details of education and experience.*

Martin
AIRCRAFT
THE GLENN L. MARTIN CO.
BALTIMORE • MARYLAND

sign development in aeronautics and in the marine field. Author of numerous technical reports, of papers, and of one book. Capable, original, cooperative, and in best physical condition. Interested in practical research and development work, preferably in consultant capacity, in or outside New York metropolitan area. Please write for particulars.

534. Aircraft Chief Engineer—Age 34. Fourteen years of diversified experience in engineering, sales, and service. This experience includes top-level management, as well as comprehensive engineering assignments. Two years as Supervisor of Service Training which included design and construction of Naval Mobile Trainers and field service; 4½ years in design and development of gun turrets; 6½ years in design development of hydraulic systems and hydraulic components; 1 year as Chief Engineer of Aviation Products Division. Had contract negotiations and contacts with most aircraft manufacturers. Interested in staff or administrative position.

533. Aeronautical Scientist—Ph.D. in Applied Mathematics. Seeks opportunity to utilize initiative and energy, coupled with broad, strong background in theory and practice of the engineering sciences. Eight years of varied experience at leading universities and in the aircraft industry: theoretical research in applied mechanics, particularly various branches of fluid mechanics; teaching of compressible flow and applied mathematics on graduate level; missile work in aerodynamics and propulsion, with emphasis on non-routine problems and methods development; research supervision; and consultant on mathematical and flow problems. Wide interests. Desires responsible position in applied research or education (or combination) in aeronautical or related fields. Complete résumé will be included in reply to inquiries that are specific. Age 29.

529. Staff Engineer—12 years' aircraft experience, including stress, liaison, design, production design, Air Force procurement and maintenance engineering, and project engineering. Currently on project staff assignment with aircraft manufacturer. Desires responsible staff engineering position with smaller manufacturer on West Coast. Please state your requirements in first letter.

527. Aeronautical Engineer—Age 30. Bachelor of Aeronautical Engineering, 1948. Five years' experience in jet-engine combustion component research and design and development involving thermodynamics, internal aerodynamics, test facility design and evaluation, and heat transfer. Commercial pilot with instrument rating. Desires more responsible technical and administrative position. Will consider non-aviation or foreign association. Résumé furnished upon request.

526. Administrative—Aeronautical Engineer, B. of A.E. Desires administrative or technical position with United States firm either at home or abroad. Extensive aeronautical experience (design, structures, and production), as well as administrative experience (systems and new products). Excellent personal and professional references. Salary of secondary importance to opportunity. Present position as an Administrative Engineer for an air line.

525. Aviation Executive—Captain, Naval Air Reserve. Twenty-five years' Naval aviation flight and executive experience; 6,500 hours all types, including jet. Current commercial license instrument rated. Desires connection with aviation accessories, manufacturers, oil companies, or airport management. Utilization of flight ability with position if necessary. Salary commensurate with position and advancement opportunities.

523. Engineer—Executive; B.S. in Aeronautical Engineering. Ten years' diversified experience, including engineering, tooling, service engineering, and manufacturing. Recent administrative and supervisory experience. Desires responsible position utilizing diversified background. Résumé upon request.

OUTSTANDING ENGINEERING OPPORTUNITY

Are you a specialist or a recent graduate proficient or interested in one or more of the following fields?

- **Aero-thermodynamics**
- **Internal Aerodynamics**
- **External Aerodynamics**
- **Ballistics**
- **Ram Jet and Turbo Jet Test and Performance**
- **Transonic and Supersonic Test Operations**
- **Turbine and Compressor Design**

Sverdrup & Parcel, Inc., is engaged in the design of advanced and unusual aeronautical test facilities which require the theory and application of the special fields. The wide variety of our work, embracing the design of general industrial facilities of all types, offers challenging problems and provides excellent opportunity for individual development and advancement. Starting salary and extent of responsibility are dependent upon individual ability and experience. Fringe benefits include: an unusually attractive Employee Benefit Plan which furnishes insurance features and provides for retirement; paid vacations, holidays and sick leave; overtime rates; and an employee's club which offers interesting social and practical values. Two accredited universities offer opportunity for advanced education.

Your letter of inquiry will receive prompt attention and reply. Please write to—

SVERDRUP & PARCEL, Inc.
Consulting Engineers
915 OLIVE ST. ST. LOUIS 1, MO.

522. Sales Engineer—B.S. in C.E. Fifteen years' diversified aircraft experience, including design, estimating, and planning. Presently employed. Current salary $8,000. Well acquainted with all phases of aircraft industry. Recent aptitude tests indicate outstanding sales ability. Would like to represent equipment manufacturer contacting aircraft and metal-working industry. Prefers Midwest or Dallas-Fort Worth area.

521. Aeronautical Engineer—Age 35. Thirteen years' experience covering structural and mechanical design, flight-test engineering, liaison, field service, and project work. Well acquainted with all phases of airplane and missile operation and design. Desires position of responsibility in administrative engineering or sales with aircraft petroleum, or air-line company. Prefers West Coast. Top professional and personal references.

520. Aeronautical Engineer—B.S.E., University of Michigan, specializing in propulsion. Commercial pilot. Presently employed with a West Coast aircraft company in the test department; 18 months' experience in test including jet-engine testing. Desires to relocate in the East or Midwest. Air Force veteran, married, age 29.

519. Field Engineer, Sales and Service—B.S.Ae.E. Age 31. Varied experience in aeronautical, mechanical, and electronic fields. Extensive travel through Europe as senior field engineer on radar and gun-fire control equipment, both air-borne and antiaircraft. Extensive experience as instructor on air-borne gun-fire control equipment, in various languages. Speaks, reads, and writes Spanish, French, Italian, Portuguese, and English. Desires responsible position as Foreign Field Engineering Representative in Europe or South America. Please indicate the nature and salary range of available positions.

518. Engineer, Research Administrator—B.S.A.E., B.S. in Business and Engineering Administration, M.I.T. Eleven years' broad experience as engineer, test pilot, consultant, educator, and, most recently, administrator of government research and development activities, United States and abroad. Desires connection in the organization and management of technical and scientific activities. Preferred location northeastern United States.

Sherman M. Fairchild Publication Fund Papers

No.		Member Price	Non-member Price
FF-8	Compressive Buckling of Plates Due to Forced Crippling of Stiffeners, **Parts I and II**—P. P. Bijlaard and G. S. Johnston.	$1.30	$2.00
FF-7	Natural Flight and Related Aeronautics—James L. G. Fitz Patrick.	$2.65	$3.50
FF-6	Wetted Length and Center of Pressure of Vee-Step Planing Surfaces—Experimental Towing Tank, Stevens Institute of Technology.	$1.20	$1.60
FF-5	Symposium on Standardization in Technical Information Services for Government Contractors.	$1.00	$1.00
FF-4	Finite Deflections of Curved Sandwich Plates and Sandwich Cylinders—F. K. Teichmann and Chi-Teh Wang.	$0.50	$0.85
FF-3	The Penetration of a Fluid Surface by a Wedge—Experimental Towing Tank, Stevens Institute of Technology.	$1.20	$1.60
FF-2	A Study of the Flow, Pressures, and Loads Pertaining to Prismatic Vee-Planing Surfaces—Experimental Towing Tank, Stevens Institute of Technology.	$1.20	$1.60
AHS-1	Helicopter Flight Research at NACA, Langley—Jack P. Reeder.	$0.35	$0.75
286	Linearized Treatment of Supersonic Flow Through Axi-Symmetric Ducts with Prescribed Wall Contours—Charles E. Mack, Jr., and Ignace I. Kolodner.	$0.75	$1.25
244	Wetted Area and Center of Pressure of Planing Surfaces—Experimental Towing Tank, Stevens Institute of Technology.	$0.75	$1.00
229	Wave Profile of a Vee-Planing Surface, Including Test Data on a 30° Deadrise Surface—Experimental Towing Tank, Stevens Institute of Technology.	$1.20	$1.60
170	Wave Contours in the Wake of a 10° Deadrise Planing Surface—Experimental Towing Tank, Stevens Institute of Technology.	$1.20	$1.60
169	The Discontinuous Fluid Flow Past an Immersed Wedge—Experimental Towing Tank, Stevens Institute of Technology.	$0.75	$1.00
168	Wave Contours in the Wake of a 20° Deadrise Planing Surface—Experimental Towing Tank, Stevens Institute of Technology.	$1.20	$1.60
167	On the Pressure Distribution for a Wedge Penetrating a Fluid Surface—Experimental Towing Tank, Stevens Institute of Technology.	$0.75	$1.00
166	An Analysis of the Fluid Flow in the Spray Root and Wake Regions of Flat Planing Surfaces—Experimental Towing Tank, Stevens Institute of Technology.	$1.20	$1.60
165	Theory and Practice of Sandwich Construction in Aircraft (A Symposium).	$1.85	$2.50
164	Applications of the Theory of Free Molecule Flow to Aeronautics—Holt Ashley.	$1.15	$1.50
106	Measurement of Ambient Air Temperature in Flight—W. Lavern Howland.	$0.35	$0.50
104	Tensor Analysis of Aircraft Structural Vibration—Charles E. Mack, Jr.	$1.85	$2.50
102	Electrical Resistance Strain Gages Applied to Wind-Tunnel Balances—Elmer C. Lundquist.	$0.60	$0.80
101	Introduction to Shock Wave Theory—J. G. Coffin.	$2.65	$3.50
100	Blade Pitching Moments of a Two-Bladed Rotor—R. W. Allen.	$0.75	$1.00
126	External Sound Levels of Aircraft—R. L. Field, T. M. Edwards, Pell Kangas, and G. L. Pigman.	$0.75	$1.00

Papers should be ordered by number from:

Publications Department, Institute of the Aeronautical Sciences, Inc.

2 East 64th Street, New York 21, N.Y.

Index to the

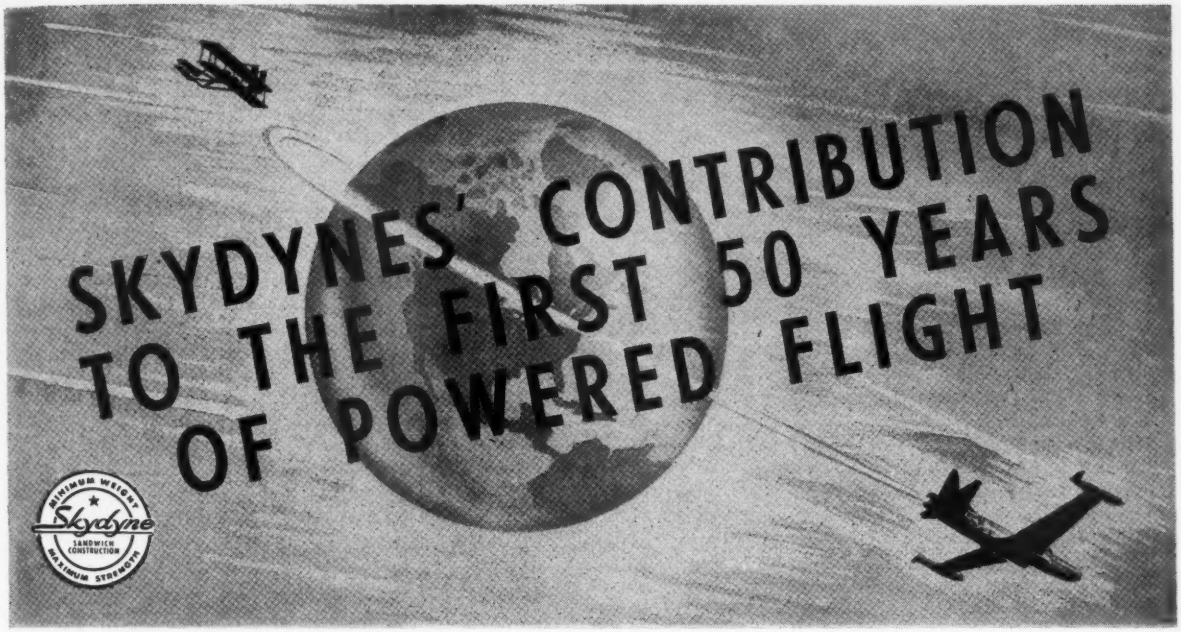
Aeronautical Engineering Review, Volume 12

January—December, 1953

	Month	Page
Aerodynamics—		
Aerodynamics—Theory, Experiment, Application, Hugh L. Dryden	*Dec.*	88
Boundary-Layer Control and Supercirculation, John S. Attinello	*Sept.*	24
Evidences of an Inherent Error in Measurement of Total-Head Pressure at Supersonic Speeds, James S. Murphy	*Nov.*	47
Laboratory Simulation of Aerodynamic Heating for Transient Temperature Measurements, L. H. Wilson and J. B. Falk	*Feb.*	39
Air Transport—		
Air-Line Point of View on Status of the Turbine-Powered Transport in the United States, Milton W. Arnold	*Aug.*	37
Aircraft Approach Tolerances, Arthur E. Jenks	*Aug.*	43
Crash Protection in Air Transports, Lt. Col. John P. Stapp, USAF (M.C.)	*Apr.*	71
Design Trends—Transport, A. E. Raymond	*Dec.*	60
Noise—A Problem in Air Transport and in Ground Operation, Lt. Col. James E. Lett, USAF (M.C.)	*Apr.*	65
The Status of the Turbine-Powered Transport in the United States, Frederick B. Lee	*Aug.*	29
Turbine-Powered Commercial Aircraft, Adm. DeWitt C. Ramsey USN (Ret.)	*Aug.*	34
American standard letter symbols for aeronautical sciences, a proposed revision of	*Jan.*	41
ARNOLD, MILTON W. Air-Line Point of View on Status of the Turbine-Powered Transport in the United States	*Aug.*	37
ATTINELLO, JOHN S. Boundary-Layer Control and Supercirculation	*Sept.*	24
Aviation History—		
Aerodynamics—Theory, Experiment Application, Hugh L. Dryden	*Dec.*	88
Design of Military Aircraft, J. H. Kindelberger	*Dec.*	42
Design Trends in 50 Years—Civil Aviation Other Than Transport, T. P. Wright	*Dec.*	74
Design Trends—Guided Missiles, Clark B. Millikan	*Dec.*	82
Design Trends—Transport, A. E. Raymond	*Dec.*	60
Evolution of Naval Aircraft, 1911–1954, Rear Adm. Lawrence B. Richardson, USN (Ret.)	*Dec.*	50
Instruments and Control of Flight, Preston R. Bassett	*Dec.*	118
A Slipstream View of Aircraft Propulsion, 1903–1953, Frank W. Caldwell	*Dec.*	108
Structures—Theory, Materials, Methods, Hall L. Hibbard	*Dec.*	96
Why 1903?, J. C. Hunsaker	*Dec.*	40
Aviation Medicine—		
Aeromedical Problems for Nuclear-Propelled Aircraft, Lt. Col. John E. Pickering, USAF	*Apr.*	69
Atmospheric Characteristics of Greatest Human Significance in Aviation of the Next Decade, Col. Paul A. Campbell, USAF (M.C.)	*Apr.*	50
Crash Protection in Air Transports, Lt. Col. John P. Stapp, USAF (M.C.)	*Apr.*	71
Impact of Modern Aviation on Health, Lt. Col. Harold V. Ellingson, USAF (M.C.)	*Apr.*	79
Noise—A Problem in Air Transport and in Ground Operation, Lt. Col. James E. Lett, USAF (M.C.)	*Apr.*	65
Physiological Aspects of Prolonged Flight at High Altitudes and Survival in Emergencies, Ulrich C. Luft, M.D.	*Apr.*	56
Predictive Diagnosis, G. J. Kidera, M.D.	*Mar.*	31
Survival Worldwide, Paul H. Nesbitt	*Mar.*	55
Trends and Transition in Aeromedical Problems with a View Toward the Next Ten Years, Brig. Gen. Otis O. Benson, Jr., USAF (M.C.)	*Apr.*	45
Vision at High Speed and Altitude, Col. Victor A. Byrnes, USAF (M.C.)	*Apr.*	61
BADGER, D. M. Analysis and Design of Multi-post-Stiffened Wings	*July*	45
BANKS, F. R. The Birth of an Engine	*June*	31
BARNABY, ROLAND E., JOHN B. CHATTERTON, AND FRED H. GERRING. General Theory and Operational Characteristics of the Gyrotron Angular Rate Tachometer	*Nov.*	31
BASSETT, PRESTON R. Instruments and Control of Flight	*Dec.*	118
BENSON, BRIG. GEN. OTIS O., JR., USAF (M.C.). Trends and Transition in Aeromedical Problems with a View Toward the Next Ten Years	*Apr.*	45
BRAHAM, WILLIAM E. The Trend of Complete Aircraft and Guided-Missile Structures Toward Reinforced Plastics	*Sept.*	37
BYRNES, COL. VICTOR A., USAF (M.C.) Vision at High Speed and Altitude	*Apr.*	61
CALDWELL, FRANK W. A Slipstream View of Aircraft Propulsion, 1903–1953	*Dec.*	108
CAMPBELL, COL. PAUL A., USAF (M.C.). Atmospheric Characteristics of Greatest Human Significance in Aviation of the Next Decade	*Apr.*	50
CARHART, RICHARD R. Reliability in Guided-Missile Systems	*Feb.*	22
CHATTERTON, JOHN B., ROLAND E. BARNABY, AND FRED H. GERRING. General Theory and Operational Characteristics of the Gyrotron Angular Rate Tachometer	*Nov.*	31
CLIETT, CHARLES B. Structural Comparison of Perforated Skin Surfaces with Other Means of Effecting Boundary-Layer Control by Suction	*Sept.*	46
COTECCHIA, U. A., V. S. HANEMAN, L. L. RAUCH, AND R. J. LEITE. Automatic Reduction of Wind-Tunnel Data	*Feb.*	42
CURRAN, ROBERT W., AND JOEL D. PETERSON. Electronics—Adaptability to Aircraft Engine Control	*May*	70

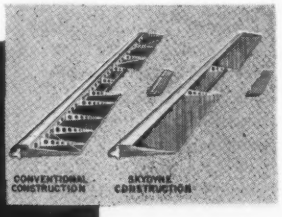
	Month	Page
DE HAVEN, HUGH. Rearward- and Forward-Facing Seats	*Mar.*	40
Design—		
Airplane Weight and Cost Can Be Reduced, E. H. Heinemann	*Jan.*	20
Design Trends in 50 Years—Civil Aviation Other Than Transport, T. P. Wright	*Dec.*	74
Evidences of an Inherent Error in Measurement of Total-Head Pressure at Supersonic Speeds, James S. Murphy	*Nov.*	47
The H Factor in Engineering Design, Clifford Seitz	*Mar.*	42
Optimum Design Considerations for Aircraft Wing Structures, Aaron L. Kolom	*Oct.*	31
Rearward- and Forward-Facing Seats, Hugh De Haven	*Mar.*	40
DODGE, BEVERLY A. The Wright Reproduction	*Oct.*	24
DOOLITTLE, JAMES H. Annual Summer Meeting Dinner Remarks (*Editorial*)	*Oct.*	23
DRYDEN, HUGH L. Aerodynamics—Theory, Experiment, Application	*Dec.*	88
Editorial—		
Activity Factor	*Feb.*	20
Annual Summer Meeting Dinner Remarks, James H. Doolittle	*Oct.*	23
Another "Mission Accomplished"	*Nov.*	22
Deus ex Machina	*Apr.*	26
Discussing Discussions	*Aug.*	22
Electronics vs. The Human	*May*	36
Fourth International Aeronautical Conference	*June*	22
Hail—and Farewell	*Jan.*	18
One One-Hundredth of One Per Cent	*Mar.*	22
They Looked to the Future	*Dec.*	38
Wright Replica	*July*	22
Electronics—		
Aircraft Omnidirectional Antenna Problem for U.H.F. Navigation Systems, A. G. Kandoian	*May*	75
Electronics—Adaptability to Aircraft Engine Control, Joel D. Peterson and Robert W. Curran	*May*	70
Symposium—Electronic Control and Stabilization of Aircraft	*May*	38
Systematic Cooling of Air-Borne Electronic Equipment, Walter Robinson	*May*	81
What Magnetic Amplifiers Can Do to Increase Aircraft Reliability, George F. Schroeder	*May*	92
ELLINGSON, LT. COL. HAROLD V., USAF (M.C.). Impact of Modern Aviation on Health	*Apr.*	79
ELLIS, CHARLES W. Effects of Articulated Rotor Dynamics on Helicopter Automatic Control System Requirements	*July*	30
ELLIS, COL. FRANK W., USAF. Incident Reporting	*Mar.*	32
FALK, J. B., AND L. H. WILSON. Laboratory Simulation of Aerodynamic Heating for Transient Temperature Measurements	*Feb.*	39
Flight Propulsion—		
Afterburners—Are They Worth While?, Floyd C. Newton	*Oct.*	42
Air-Line Point of View on Status of the Turbine-Powered Transport in the United States, Milton W. Arnold	*Aug.*	37
The Birth of an Engine, F. R. Banks	*June*	31
MATS and the Gas-Turbine Transport Field, Lt. Gen. Joseph Smith, USAF	*Aug.*	40
Optimum Exit-Nozzle Performance for Jet Engines, Richard G. Laucher and John S. Winter	*Sept.*	41
A Slipstream View of Aircraft Propulsion, 1903–1953, Frank W. Caldwell	*Dec.*	108
Spreading of Supersonic Jets in Supersonic Streams, John G. Wilder, Jr., and Kenneth Hindersinn	*Oct.*	54
The Status of the Turbine-Powered Transport in the United States, Frederick B. Lee	*Aug.*	29
Turbine-Powered Commercial Aircraft, Adm. DeWitt C. Ramsey, USN (Ret.)	*Aug.*	34
FURNAS, C. C. The Next Half Century	*June*	24
GERRING, FRED H., ROLAND E. BARNABY, AND JOHN B. CHATTERTON. General Theory and Operational Characteristics of the Gyrotron Angular Rate Tachometer	*Nov.*	31
GOUGH, M. N., AND A. W. VOGELEY. A Simple Thrust Indicator for Propeller-Driven Airplanes	*June*	47
HANEMAN, V. S., L. L. RAUCH, R. J. LEITE, AND U. A. COTECCHIA. Automatic Reduction of Wind-Tunnel Data	*Feb.*	42
HAYNES, B. C. Final Approach Visibility Studies at Airports in the United States	*Mar.*	44
HEINEMANN, E. H. Airplane Weight and Cost Can Be Reduced	*Jan.*	20
HIBBARD, HALL L. Structures—Theory, Materials, Methods	*Dec.*	96
HINDERSINN, KENNETH, AND JOHN G. WILDER, JR. Spreading of Supersonic Jets in Supersonic Streams	*Oct.*	54
HOFF, N. J. Eighth International Congress on Theoretical and Applied Mechanics	*Feb.*	48
HOLM, HARVEY. Design of the Hiller HJ-1, YH-32 Helicopter	*Oct.*	48
HOPGOOD, R. C. A Proposed Revision of American Standard Letter Symbols for Aeronautical Sciences	*Jan.*	41
HUBBELL, WILSON G. Jet Metals	*Sept.*	31
HUNSAKER, J. C. Why 1903?	*Dec.*	40
Institute of the Aeronautical Sciences—		
Aero Medical Association Elects Officers	*Aug.*	19
Air Baggage Label Collection	*Sept.*	18
Aircraft Quality Control Conference	*Sept.*	18
Annual Business Meeting of the Institute	*Mar.*	17
Annual Summer Meeting, Report of Technical Sessions	*Oct.*	28
A.T.A. Forms Helicopter-Study Committee	*Apr.*	25
Aviation Medicine Now Preventative Medicine Specialty	*May*	34
Bane and Chanute Awards Presented	*Aug.*	17
Comments on the Twenty-First Annual Meeting	*Apr.*	17
Convertible Aircraft Congress, 2nd	*Apr.*	88
Sir Geoffrey de Havilland Awarded Guggenheim Medal for 1952	*Feb.*	17
Director's Report—1952	*Mar.*	20
General Doolittle Receives Wright Trophy	*Feb.*	18
Eighth International Congress on Theoretical and Applied Mechanics, N. J. Hoff	*Feb.*	48
Fellowships in the Institute	*Apr.*	21
Flight Propulsion Meeting—Cleveland, Ohio, March 13, 1953	*June*	18
Flight Safety Course Organized	*Oct.*	20
Flight Safety Foundation Presents Awards	*Feb.*	18
Fluid Mechanics Conference Planned	*Mar.*	62
Four Air-Line Corporate Members Cited	*Sept.*	18
Fourth International Aeronautical Conference	*July*	17

	Month	Page
Fourth International Aeronautical Conference Set for September	*Jan.*	15
Fourth Plasticity Symposium	*June*	20
Fourth Southeastern Conference	*July*	18
Guggenheim Fellowships at CalTech	*Aug.*	20
Guggenheim Fellowships at Princeton	*Sept.*	18
1953 Guggenheim Medal Awarded to Charles A. Lindbergh	*Dec.*	35
N. J. Hoff to Present RAeS Wright Lecture	*June*	21
Honorary Fellows for 1952	*Apr.*	21
IAS Awards and Honors for 1952	*Apr.*	22
IAS Members Among M.A.A. Executive	*Apr.*	25
IAS Officers for 1953	*Apr.*	20
IAS San Diego Building Reopened	*May*	33
IAS Staff Changes	*July*	21
IAS 21st Annual Meeting—Summary of Technical Sessions	*Apr.*	28
IAS Twenty-Second Annual Meeting	*Nov.*	19
IAS Visits the Navy	*Feb.*	16
National Safety Council's Award Winners	*May*	34
Newly Elected Members of the Institute Council	*Apr.*	24
Northeast IAS Student Branches Hold First Regional Meeting	*Aug.*	18
P.A.L. Holds Documentation Seminars	*Apr.*	25
Pioneer Manufacturer to Present 1953 Wright Brothers Lecture	*Oct.*	19
Pioneers Committee Formed	*July*	21
Preliminary Announcement of 1953 Annual Summer Meeting	*June*	17
Presentation of The Thurman H. Bane Award	*Jan.*	17
President's Report—1952	*Mar.*	18
RAeS Installs New President	*July*	21
RAeS President-Elect	*Oct.*	20
Report of Third Annual West Coast Conference of IAS Student Branches	*Aug.*	19
Sixteenth Wright Lecture	*Feb.*	15
John Stack Co-Recipient of Collier Trophy for Second Time	*Feb.*	17
Summer Meeting Sets Attendance Record for Coast	*Sept.*	17
Testing Laboratory Formed by IAS Members	*Nov.*	20
Texas Section's First Southwestern Student Competition	*July*	19
Treasurer's Report	*Mar.*	18
University of Michigan Names Department Head and Establishes New Professorship	*Dec.*	36
Gen. Hoyt S. Vandenberg to Speak at Honors Night Dinner	*Jan.*	16
The Wright Reproduction, Beverly A. Dodge	*Oct.*	24
Instruments—		
Aircraft Approach Tolerances, Arthur E. Jenks	*Aug.*	43
Final Approach Visibility Studies at Airports in the United States, B. C. Haynes	*Mar.*	44
General Theory and Operational Characteristics of the Gyrotron Angular Rate Tachometer, Roland E. Barnaby, John B. Chatterton, and Fred H. Gerring	*Nov.*	31
Instruments and Control of Flight, Preston R. Bassett	*Dec.*	118
A New Space Rate Sensing Instrument, Joseph Lyman	*Nov.*	24
JENKS, ARTHUR E. Aircraft Approach Tolerances	*Aug.*	43
KANDOIAN, A. G. Aircraft Omnidirectional Antenna Problem for U.H.F. Navigation Systems.	*May*	75
KIDERA, G. J., M.D. Predictive Diagnosis	*Mar.*	31
KINDELBERGER, J. H. Design of Military Aircraft	*Dec.*	42
KING, BARRY. Elimination of Some Time Losses in Emergency Evacuation of Passengers from Airplanes	*Mar.*	37
KOLOM, AARON L. Optimum Design Considerations for Aircraft Wing Structures	*Oct.*	31
LAUCHER, RICHARD G., AND JOHN S. WINTER. Optimum Exit-Nozzle Performance for Jet Engines	*Sept.*	41
LEDERER, JEROME. The Bermuda Air Safety Seminar of 1952	*Mar.*	25
LEE, FREDERICK B. The Status of the Turbine-Powered Transport in the United States	*Aug.*	29
LEITE, R. J., V. S. HANEMAN, L. L. RAUCH, AND U. A. COTECCHIA. Automatic Reduction of Wind-Tunnel Data	*Feb.*	42
LEMAY, GEN. CURTIS E., USAF. Strategic Air Command	*Sept.*	20
LETT, LT. COL. JAMES E., USAF (M.C.) Noise—A Problem in Air Transport and in Ground Operation	*Apr.*	65
LEWIS, FLOYD A. How to Buy Aluminum Castings	*Jan.*	34
LUFT, ULRICH C., M.D. Physiological Aspects of Prolonged Flight at High Altitudes and Survival in Emergencies	*Apr.*	56
LYMAN, JOSEPH. A New Space Rate Sensing Instrument	*Nov.*	24
Materials—		
How to Buy Aluminum Castings, Floyd A. Lewis	*Jan.*	34
Jet Metals, Wilson G. Hubbell	*Sept.*	31
Structures—Theory, Materials, Methods, Hall L. Hibbard	*Dec.*	96
The Trend of Complete Aircraft and Guided-Missile Structures Toward Reinforced Plastics, William E. Braham	*Sept.*	37
MCCORMICK, T. F. Large Extrusion-Press Operation and Production Problems in Aluminum	*Feb.*	27
Military Aviation—		
Air Power and New Weapons, Gen. Hoyt S. Vandenberg, USAF	*Apr.*	18
Combat-Ready Aircraft, Col. B. A. Schriever, USAF	*Feb.*	34
Design of Military Aircraft, J. H. Kindelberger	*Dec.*	42
Evolution of Naval Aircraft, 1911–1954, Rear Adm. Lawrence B. Richardson, USN (Ret.)	*Dec.*	50
MATS and the Gas-Turbine Transport Field, Lt. Gen. Joseph Smith, USAF	*Aug.*	40
Military Air Cargo Carrier Trends, Walter Tydon	*July*	39
Recent Developments in the Navy's Air Arm, Capt. J. N. Murphy, USN	*Aug.*	24
Strategic Air Command, Gen. Curtis E. LeMay, USAF	*Sept.*	20
MILLIKAN, CLARK B. Design Trends—Guided Missiles	*Dec.*	82
Missiles—		
Design Trends—Guided Missiles, Clark B. Millikan	*Dec.*	82
Guided Missiles—Comments on Surface-Based Antiaircraft Missiles, Henry H. Porter	*July*	24
Reliability in Guided-Missile Systems, Richard R. Carhart	*Feb.*	22

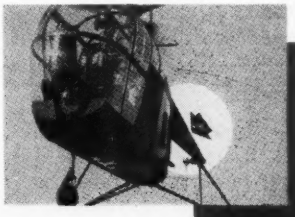


In the midst of the fastest moving age the world has ever known, it is well to stop and give honor to the accomplishment of this age, which has most captured the imaginations of the people as a whole . . . Powered Flight, and to the names which have come to be synonymous with Powered Flight, Wilbur and Orville Wright.

Almost as wonderful as the aeroplane itself has been the rapid improvement in the quality of its flight and its blinding speed, which has tended to shrink the very world we live in. This vast improvement during the industry's infant years has been in great measure due to hundreds of little people and thousands of inventions, all tiny in themselves but as a whole, great in their power to improve. We at Skydyne are proud to have been responsible for a few of these improvements:

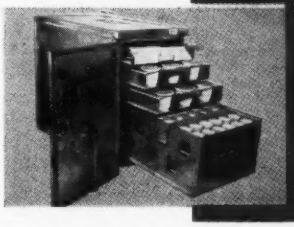


SKYDYNE DESIGNED AND BUILT FIRST SANDWICH TYPE AILERONS
Skydyne developed, designed and constructed the first sandwich type primary structure ever used in the U. S. This was an aileron for the SNJ-2 in 1940.



SKYDYNE DESIGNED AND BUILT FIRST TRUE SANDWICH MONOCOQUE FUSELA
Skydyne designed and built the first true sandwich monocoque fuselage tail boom. First used in the GA-45 Helicopter in 1944. This revolutionary construction minimized vibration and greatly reduced the weight of this type construction.

SKYDYNE BUILT FIRST SAND ICH TYPE ROTOR BLADE
Skydyne designed and built the first sandwich type rotor blade for the Air Forces. It was first used in Helicopter XR-G in 1944.



SKYDYNE DESIGNED AND BUILT FIRST SANDWICH TYPE FOOD LOCKER
Designed for a major air line, the new type food locker was of lightweight durable construction. It consisted of aluminum faces with a light insulating material as a core. It preserved foods for specified flight times.

SKYDYNE BUILT LIGHTWEIGHT SPARE PARTS CASES FOR B-29
Skydyne designed and built lightweight spare parts cases for the famous B-29. This unique case allowed the crew chief to keep track of valuable spare parts; kept the famous ships flying longer.

SKYDYNE IN BASIC RESEARCH
Skydyne carried on, sponsored and published the first basic data on sandwich material and sandwich structure. This and subsequent work was conducted by Dr. S. E. Mautner, chief engineer of Skydyne, and Dr. Nicholas J. Hoff. This data is widely quoted and is used as reference material and in text books. It was first presented on April 27, 1944, at the National Light Aircraft Meeting of the Institute of Aeronautical Sciences, in Detroit.

SKYDYNE BUILT FIRST AIRBORNE CASE FOR SIGNAL CORPS
Skydyne designed and built the first lightweight, sandwich type, airborne radar antenna and radar instrument cases for the Signal Corps in 1942. Lighter in weight and smaller in overall volume, they helped save valuable payload.

SKYDYNE ORIGINATED SANDWICH CONSTRUCTION IN THE UNITED STATES . . . SKYDYNE OWNS THE FIRST PATENT FOR SANDWICH TYPE CONSTRUCTION EVER ISSUED IN THE UNITED STATES.

SKYDYNE Inc. RIVER ROAD, PORT JERVIS, NEW YORK

	Month	Page
MURPHY, CAPT. J. N., USN. Recent Developments in the Navy's Air Arm	*Aug.*	24
MURPHY, JAMES S. Evidences of an Inherent Error in Measurement of Total-Head Pressure at Supersonic Speeds	*Nov.*	47
Necrology—		
Roland Belisle	*Dec.*	37
Frank P. Callahan	*Mar.*	62
Capt. Phillip M. Clinton	*Dec.*	37
Philip R. Conrath	*June*	66
M. B. Crawford	*Dec.*	37
Justin A. Fitz	*Feb.*	51
Sherman S. Graves	*Mar.*	63
John D. Hubbard	*June*	66
John F. Jacobs, Jr.	*June*	66
Mark A. Klinger	*July*	21
Wilbur R. Lindsey, Jr.	*Jan.*	17
Flavius E. Loudy	*June*	66
James E. Madden	*Dec.*	37
John C. Marsh	*Dec.*	37
Minta Martin	*May*	34
M. N. Pack	*Oct.*	21
Major R. W. Schroeder	*Mar.*	63
James O. Seay	*Dec.*	73
Carl J. Stubau	*Oct.*	21
Ens. Forrest D. Swisher	*Feb.*	51
Rudolph D. Van Dyke, Jr.	*Dec.*	37
Dr. Richard von Mises	*Oct.*	21
Charles W. Weaver, Jr.	*Nov.*	20
Dr. Theodor W. Zobel	*Sept.*	18
NESBITT, PAUL H. Survival Worldwide	*Mar.*	55
NEWTON, FLOYD C. Afterburners—Are They Worth While?	*Oct.*	42
Noise, external aircraft, a review of the problem of	*Mar.*	49
Noise—A problem in air transport and in ground operation	*Apr.*	65
PAPEN, GEORGE W. Requirements for Large, Light-Metal Forgings and Extrusions in the Aircraft Industry	*Jan.*	24
PETERSON, JOEL D., AND ROBERT W. CURRAN. Electronics—Adaptability to Aircraft Engine Control	*May*	70
PICKERING, LT. COL. JOHN E., USAF. Aeromedical Problems for Nuclear-Propelled Aircraft	*Apr.*	69
PORTER, HENRY H. Guided Missiles—Comments on Surface-Based Antiaircraft Missiles	*July*	24
POSNER, DAVID L. Propeller Reversing Problems	*June*	44
Production—		
How to Buy Aluminum Castings, Floyd A. Lewis	*Jan.*	34
Large Extrusion-Press Operation and Production Problems in Aluminum, T. F. McCormick	*Feb.*	27
Requirements for Large, Light-Metal Forgings and Extrusions in the Aircraft Industry, George W. Papen	*Jan.*	24
Propellers—		
Propeller Reversing Problems, David L. Posner	*June*	44
A Simple Thrust Indicator for Propeller-Driven Airplanes, A. W. Vogeley and M. N. Gough	*June*	47
RAMSEY, ADM. DEWITT C., USN (RET.). Turbine-Powered Commercial Aircraft	*Aug.*	34
RAUCH, L. L., V. S. HANEMAN, R. J. LEITE, AND U. A. COTECCHIA. Automatic Reduction of Wind-Tunnel Data	*Feb.*	42
RAYMOND, A. E. Design Trends—Transport	*Dec.*	60
REDLICH, O., AND F. R. WATSON. On Programs for Tests Involving Several Variables	*June*	51
Research—		
On Programs for Tests Involving Several Variables, O. Redlich and F. R. Watson	*June*	51
RICHARDSON, REAR ADM. LAWRENCE B., USN (RET.). Evolution of Naval Aircraft, 1911–1954	*Dec.*	50
ROBINSON, WALTER. Systematic Cooling of Air-Borne Electronic Equipment	*May*	81
Rotating Wing Aircraft—		
Design of the Hiller HJ-1, YH-32 Helicopter, Harvey Holm	*Oct.*	48
Effects of Articulated Rotor Dynamics on Helicopter Automatic Control System Requirements, Charles W. Ellis	*July*	30
Safety—		
The Bermuda Air Safety Seminar of 1952, Jerome Lederer	*Mar.*	25
Elimination of Some Time Losses in Emergency Evacuation of Passengers from Airplanes, Barry King	*Mar.*	37
Final Approach Visibility Studies at Airports in the United States, B. C. Haynes	*Mar.*	44
The H Factor in Engineering Design, Clifford Seitz	*Mar.*	42
Incident Reporting, Col. Frank W. Ellis, USAF	*Mar.*	32
Predictive Diagnosis, G. J. Kidera, M.D.	*Mar.*	31
Rearward- and Forward-Facing Seats, Hugh De Haven	*Mar.*	40
A Review of the Problem of External Aircraft Noise, Karl D. Swartzel	*Mar.*	49
Survival Worldwide, Paul H. Nesbitt	*Mar.*	55
SCHRIEVER, COL. B. A., USAF. Combat-Ready Aircraft	*Feb.*	34
SCHROEDER, GEORGE F. What Magnetic Amplifiers Can Do to Increase Aircraft Reliability	*May*	92
SEITZ, CLIFFORD. The H Factor in Engineering Design	*Mar.*	42
SMITH, LT. GEN. JOSEPH, USAF. MATS and the Gas-Turbine Transport Field	*Aug.*	40
STAPP, LT. COL. JOHN P., USAF (M.C.). Crash Protection in Air Transports	*Apr.*	71
Stress Analysis & Structures—		
Analysis and Design of Multipost-Stiffened Wings, D. M. Badger	*July*	45
Fatigue Life of Thick-Skinned Tension Joints, Edward W. Thrall, Jr.	*Nov.*	37
Optimum Design Considerations for Aircraft Wing Structures, Aaron L. Kolom	*Oct.*	31
Requirements for Large, Light-Metal Forgings and Extrusions in the Aircraft Industry, George W. Papen	*Jan.*	24
Structural Comparison of Perforated Skin Surfaces with Other Means of Effecting Boundary-Layer Control by Suction, Charles B. Cliett	*Sept.*	46
The Trend of Complete Aircraft and Guided-Missile Structures Toward Reinforced Plastics, William E. Braham	*Sept.*	37
SWARTZEL, KARL D. A Review of the Problem of External Aircraft Noise	*Mar.*	49
THRALL, EDWARD W., JR. Fatigue Life of Thick-Skinned Tension Joints	*Nov.*	37
TYDON, WALTER. Military Air Cargo Carrier Trends	*July*	39

	Month	Page
VANDENBERG, GEN. HOYT S., USAF. Air Power and New Weapons	*Apr.*	18
VOGELEY, A. W., AND M. N. GOUGH. A Simple Thrust Indicator for Propeller-Driven Airplanes	*June*	47
WATSON, F. R., AND O. REDLICH. On Programs for Tests Involving Several Variables	*June*	51
WILDER, JOHN G., JR., AND KENNETH HINDERSINN. Spreading of Supersonic Jets in Supersonic Streams	*Oct.*	54
WILSON, L. H., AND J. B. FALK. Laboratory Simulation of Aerodynamic Heating for Transient Temperature Measurements	*Feb.*	39
Wind Tunnels—		
Automatic Reduction of Wind-Tunnel Data, V. S. Haneman, L. L. Rauch, R. J. Leite, and U. A. Cotecchia	*Feb.*	42
Spreading of Supersonic Jets in Supersonic Streams, John G. Wilder, Jr., and Kenneth Hindersinn	*Oct.*	54
WINTER, JOHN S., AND RICHARD G. LAUCHER. Optimum Exit-Nozzle Performance for Jet Engines	*Sept.*	41
WRIGHT, T. P. Design Trends in 50 Years—Civil Aviation Other Than Transport	*Dec.*	74

Keep Posted on New Aircraft Products and Product Literature

Make it a habit to check the *Aeronautical Engineering Review's* "New Products Section" every month. Located at the end of each issue, it contains a complete review of all recently announced new product developments and product literature of special interest to the aeronautical profession. Handy tear-out postals are included for your convenience in requesting additional information direct from the manufacturers.

Make It a Habit—Use the "New Products Section" Every Month

AERONAUTICAL ENGINEERING REVIEW

Changes of Address

Since the Post Office Department does not as a rule forward magazines to forwarding addresses, it is important that the Institute be notified of changes in address 30 days in advance of publishing date to ensure receipt of every issue of the *Journal* and *Review*.

Notices should be printed legibly and sent directly to:
Institute of the Aeronautical Sciences
2 East 64th Street, New York 21, N.Y.

Index to

A

AC Spark Plug Division, General Motors Corporation 259
Aeronautical Engineering Catalog 294
Aeronautical Engineering Review 269, 294
Aeroproducts-Allison Division, General Motors Corporation 195
★Air Associates, Inc. 181
★Airborne Accessories Corporation 28
Aircraft Equipment Testing Company 247
Aircraft Radio Corporation 137
AiResearch Manufacturing Company Division, The Garrett Corporation 143
Allied Research Associates Inc. 301
Allison Division, General Motors Corporation 271
American Bosch Corporation, Arma Corporation Subsidiary 245
★American Brass Company, American Metal Hose Branch 263
American Chemical Paint Company 25
American Cystoscope Makers, Inc. 168
★American Phenolic Corporation 201
★American Steel & Wire Division, United States Steel Corporation 149
American Tube Bending Company, Inc. 255
Arkwright Finishing Company 255
Arma Corporation, Subsidiary of American Bosch Corporation 245
Aviation Engineering Division, Avien-Knickerbocker, Inc. 304
Avica Corporation 278

B

B.H. Aircraft Company Inc. 144
Baldwin-Lima-Hamilton Corporation 261
Barber-Colman Company 22, 23
Bell Aircraft Corporation 269
Bendix Aviation Corporation
★Bendix Products Division 157
★Eclipse-Pioneer Division 223
Pacific Division 237
★Scintilla Magneto Division 251, 301
★Borg-Warner Corporation, Pesco Products Division 153
★Bowser Technical Refrigeration Division, Bowser, Inc. 152
★Breeze Corporations, Inc. 151

C

★Cannon Electric Company 176
Century Geophysical Corporation 292
Chandeysson Electric Company 217
Clifford Manufacturing Company Division, Standard-Thomson Corporation 173
Collins Radio Company 187
Consolidated Vultee Aircraft Corporation ..... Inside Back Cover
Continental Screw Company 225
Cooper Precision Products 164
Cornelius Company, The 288
★Crane Company, Hydro-Aire Inc. Subsidiary 155

D

Dialight Corporation 160
Doelcam Corporation 234
Douglas Aircraft Company, Inc. 185
★Dow Chemical Company, The, Magnesium Department 169

E

★Eclipse-Pioneer Division, Bendix Aviation Corporation 223
★Electrical Engineering & Manufacturing Corporation 233
★Electrol Incorporated 296

F

Fairchild Engine and Airplane Corporation
★Fairchild Aircraft Division 32, 294
★Stratos Division 177
Federal Telephone and Radio Company, Selenium-Intelin Department 191
Fifty Years of Flight, Publication 267
★Flexonics Corporation, Aircraft Division 27
★Foote Bros. Gear and Machine Corporation 26
Ford Instrument Company, Division of The Sperry Corporation 14

G

Garrett Corporation, The, AiResearch Manufacturing Company Division 143
★General Controls Company 249
General Motors Corporation
AC Spark Plug Division 259
Aeroproducts-Allison Division 195
Allison Division 271
General Radio Company 8
Genisco, Incorporated 242
★G. M. Giannini & Co., Inc. 161
B. F. Goodrich Company, The 215
Goodyear Tire & Rubber Company, Inc., The, Aviation Products Department 1
Grand Central Aircraft Company 165
Grumman Aircraft Engineering Corporation 203

H

Harvey Aluminum Sales, Inc. 253
Holley Carburetor Company ..... Inside Front Cover
Hufford Machine Works Inc. 15
★Hydro-Aire Inc., Subsidiary of Crane Company 155

I

Imperial Tracing Cloth, Keuffel & Esser Company 300
Indiana Gear Works, Inc. 140
★Industrial Sound Control Inc. 194
International Nickel Company, Inc., The 31, 286

J

★Jack & Heintz, Inc. 208, 209
★Johns-Manville 4, 5
★Joy Manufacturing Company 290, 294

K

Kearfott Company, Inc. 252
★Kenyon Instrument Company, Inc. 276
Ketay Manufacturing Corporation 18
Keuffel & Esser Company 6, 7
Imperial Tracing Cloth 300
Walter Kidde & Company, Inc. 213
Koehler Aircraft Products Company, Inc. 247
Kollsman Instrument Corporation, Subsidiary of Standard Coil Products Company, Inc. 206

L

Lamb Electric Company, The 198
★Lear, Incorporated 19
★Liquidometer Corporation, The 205
Lockheed Aircraft Corporation 246, 247

M

Manning, Maxwell & Moore, Inc., Aircraft Products Division 175
Marquardt Aircraft Company 159

FOR a few fleeting hours The World's Long-Distance Record for powered flight stood at 120 feet. The endurance time was twelve seconds, and the altitude—ten feet—was sheer high-flying madness.

What happened on Kill Devil Hill that chilly December morning fifty years ago still stands as the greatest milestone in the conquest of flight.

Even in this day, when the glittering flash of silver wings precedes the sound of their passage — all the proud achievements which have since swelled the logbook owe their existence to the men at Kitty Hawk.

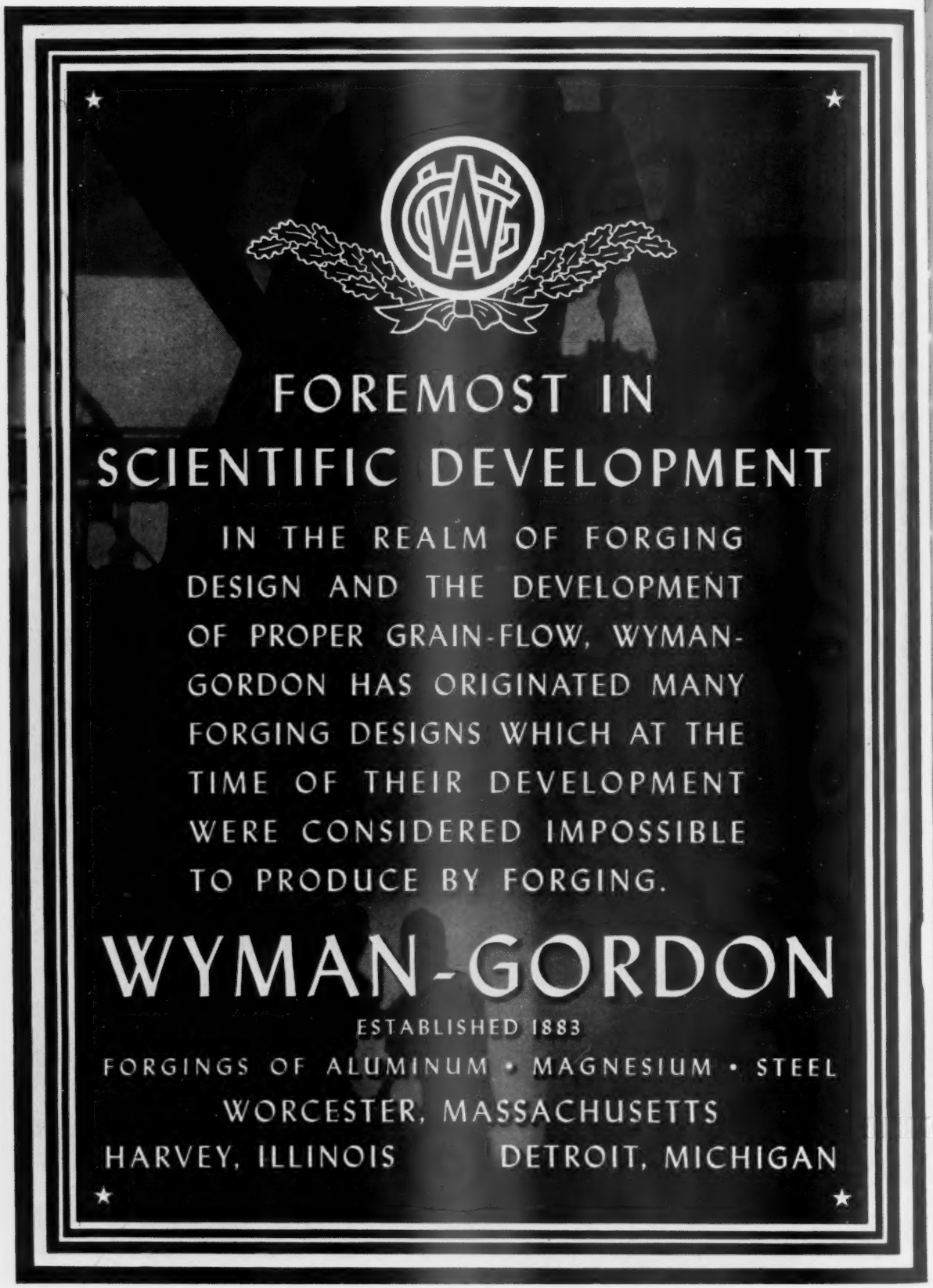
Goodyear has played a consistent part in those entries: the first Aeroplane Tire, 1909, which served on early Wright bi-planes as they set new records; Stay-Tight Aeroplane fabric which gave new lift to their wings.

Then came the bullet-sealing fuel tank, the famed Single Disc Brake, the Cross-Wind Landing Wheel, Iceguards and many other Goodyear pioneering advancements.

Almost since the very year when events on Kill Devil Hill changed the world, Goodyear Aviation Products have contributed importantly to progress in the air.

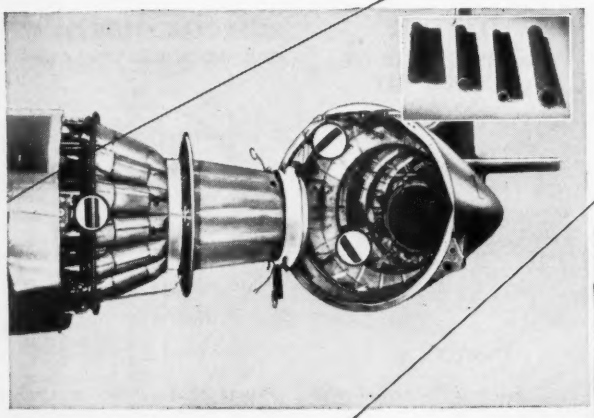
Goodyear, Aviation Products Department
Akron 16, Ohio or Los Angeles 54, California

Iceguard—T. M. The Goodyear Tire & Rubber Company, Akron, Ohio


FOREMOST IN
SCIENTIFIC DEVELOPMENT
IN THE REALM OF FORGING DESIGN AND THE DEVELOPMENT OF PROPER GRAIN-FLOW, WYMAN-GORDON HAS ORIGINATED MANY FORGING DESIGNS WHICH AT THE TIME OF THEIR DEVELOPMENT WERE CONSIDERED IMPOSSIBLE TO PRODUCE BY FORGING.
WYMAN-GORDON
ESTABLISHED 1883
FORGINGS OF ALUMINUM • MAGNESIUM • STEEL
WORCESTER, MASSACHUSETTS
HARVEY, ILLINOIS
DETROIT, MICHIGAN

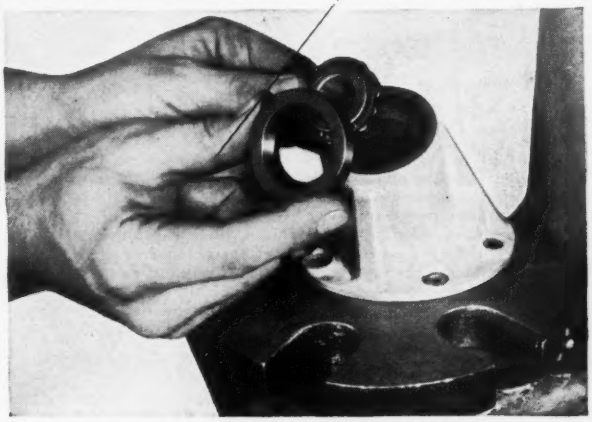
and Temperatures

...J-M Packings & Gaskets

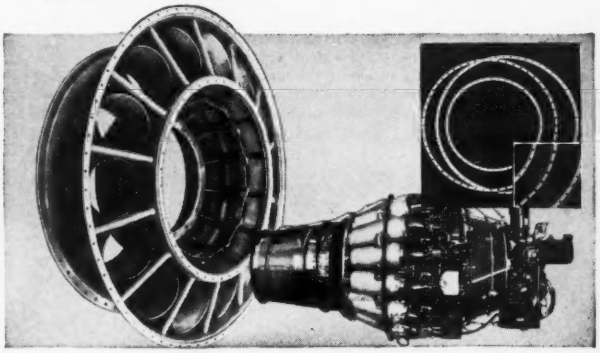


J-M Clipper Seals—used on helicopters, in rotor and gear systems, to keep abrasives out, seal oil in. Available in split form for easy application in small spaces. In addition to Clipper Seals, Johns-Manville offers special-shaped propeller seals in accordance with design specifications. Available in a wide variety of compounds and shapes such as "U," "O," "T" and "Hat-shaped."

J-M Firewall Seals—to reduce fire hazards. Besides the tadpole tapes illustrated here, Johns-Manville makes many types of asbestos cloth, tape and tubing. They are used for insulating, fireproofing, cushioning and sealing fuel, lubrication, hydraulic and electrical lines; also exhaust system shroud and cowling assemblies.



J-M Goetze Gaskets—These custom crafted metallic gaskets may be fabricated in almost any shape or size, for sealing igniters, compressor bleed-offs, cross ignition tubes and many other applications. Many types of J-M asbestos gaskets are also available for sealing, cushioning and mounting in aircraft power plants, airframes and accessories.



tremes of temperature . . . packings and gaskets to seal in lubricants and hot gases . . . asbestos textiles for fireproofing . . . friction materials to control motion.

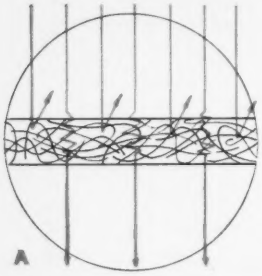
For further information about Johns-Manville Aviation Products, write for copy of booklet AV-1A. Johns-Manville, Box 60, New York 16, N. Y. In Canada, 199 Bay St., Toronto 1, Ont.

JOHNS-MANVILLE JM PRODUCTS

Products for the Aviation Industry

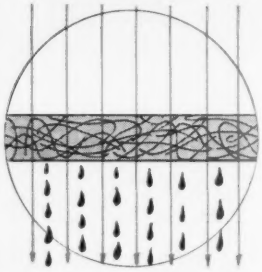
How tracing paper is made and why ALBANENE* is Different

TOUGH, LONG-FIBER PAPER
NOT TRANSPARENTIZED



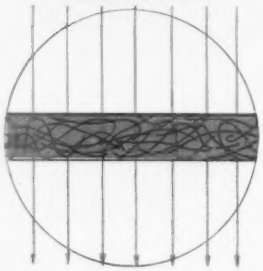
Diagrammatic enlargement of cross section of paper with high strength but low transparency. Fibers are surrounded by air, which has different index of refraction. Many light rays are bent back and do not get through.

SAME PAPER
TRANSPARENTIZED WITH FLUID MATERIAL



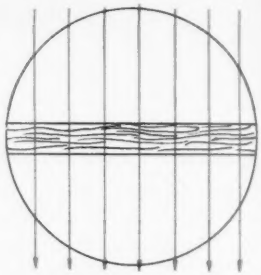
Same paper as "A", filled with oil or other fluid material, giving spaces between fibers same index of refraction as fibers. Reflection and refraction of light are reduced and paper becomes highly transparent. But transparency is not permanent because *fluids* "bleed" out.†

SAME PAPER
TRANSPARENTIZED THE ALBANENE WAY



Same paper as "A", filled with an inert synthetic resin, with correct index of refraction. This is how Albanene is made. Its transparentizer does not "bleed" out. Albanene holds its color and strength and is permanently transparent.†

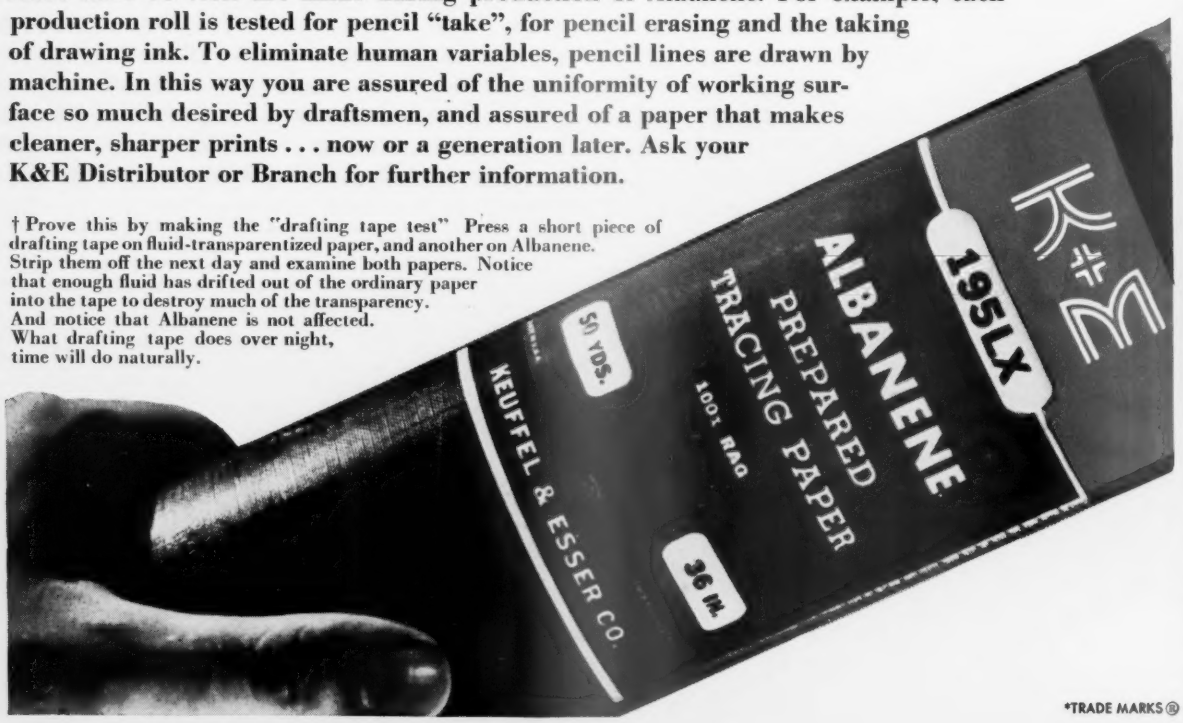
PAPER TRANSPARENTIZED BY
CRUSHING AND BEATING FIBERS



Papers are also transparentized at the mill by a "beating" process. The fibers are crushed, flattened and compacted. Reflection and refraction of light are reduced. But the process weakens the fibers and the strength of the transparent paper is low.

More than 15 tests are made during production of Albanene. For example, each production roll is tested for pencil "take", for pencil erasing and the taking of drawing ink. To eliminate human variables, pencil lines are drawn by machine. In this way you are assured of the uniformity of working surface so much desired by draftsmen, and assured of a paper that makes cleaner, sharper prints . . . now or a generation later. Ask your K&E Distributor or Branch for further information.

† Prove this by making the "drafting tape test" Press a short piece of drafting tape on fluid-transparentized paper, and another on Albanene. Strip them off the next day and examine both papers. Notice that enough fluid has drifted out of the ordinary paper into the tape to destroy much of the transparency. And notice that Albanene is not affected. What drafting tape does over night, time will do naturally.



*TRADE MARKS ®

Transparent... and Better!

AVAILABLE IN MANY FORMS FOR MANY USES

Albanene comes in 20-yard and 50-yard rolls in various widths and in three different weights. For those who like the convenience of cut sheets, a new Albanene package has been designed. It strongly protects the paper in shipment and storage, and may be opened without mutilating the container, thus serves as a dispenser in drafting room or stock room. Albanene cut sheets can be supplied imprinted to your specifications.

The Right Angle

Once you've discovered the pleasure of drawing on Albanene, the next logical step is to save time, trouble and eyesight with a K&E PARAGON* Drafting Machine. You control your calibrated straight edge with a light touch of one hand, for parallel lines and lines at any angle.

Make your lettering letter-perfect and save wear and tear on your nerves by using a LEROY* lettering outfit. Template grooves guide your pen so the finished result looks like printers' type, and the whole process is relaxing. There's a wide choice of sizes, styles and symbols.

K+E

PARTNERS IN CREATING

KEUFFEL & ESSER CO.

EST. 1867

Drafting, Reproduction, Surveying Equipment and Materials, Slide Rules, Measuring Tapes

NEW YORK • HOBOKEN, N. J.
CHICAGO • ST. LOUIS • DETROIT
SAN FRANCISCO • LOS ANGELES • MONTREAL

"the G-R Microflash has been instrumental in the development of our Analog-to-Digital Converter"

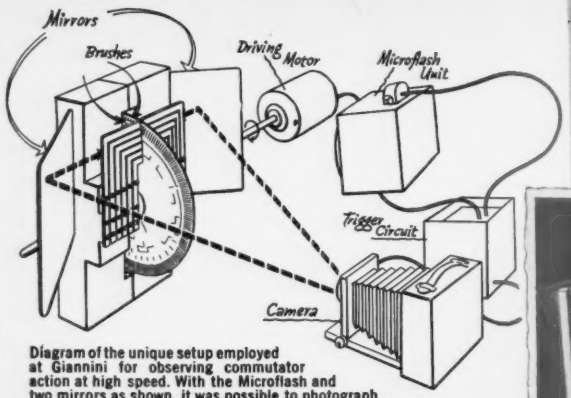
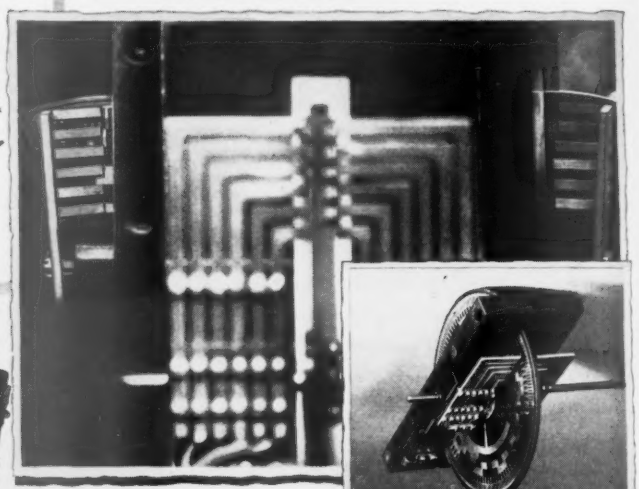
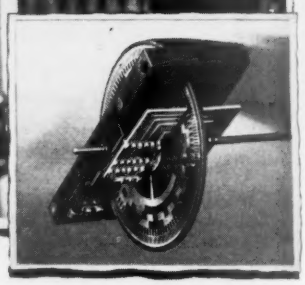


Diagram of the unique setup employed at Giannini for observing commutator action at high speed. With the Microflash and two mirrors as shown, it was possible to photograph both sides of the commutator at the same instant of time and with equal exposure.

When design engineers had to observe the brush contact points of a developmental analog to digital converter, while the commutator was actually rotating at high speed, they called for a G-R Type 1530-A Microflash. The high-intensity, short-duration flash provided by this equipment was instrumental in the development of the Giannini model 14310 Analog Position Encoder.



Photograph shows excellent results obtained with Microflash high-intensity, short-duration illumination. Back view of either side of commutator and front view are shown. Photos courtesy G. M. Giannini and Company, Inc.



Commutator of Angular Position Encoder is photo-engraved with twelve rows of conducting segments which contact twelve stationary brushes. This enables Encoder to measure angular rotation of 360 degrees with an accuracy of ±0.1%.

Type 1530-A Microflash $640

The Microflash has been successfully applied to the study of many phenomena in pure and applied science. It is widely used in studying the effects of abrasion, turbulence in liquids, and mechanical distortion at high rotational speeds.

Other applications include study of the disintegration of high-speed rotors, investigation of projectile flight and impact, and experimentation dealing with the propagation of fractures in various materials. In mechanical design, the Microflash is an indispensable tool for studying the action of springs, valves, cams, cranks, bearings and other parts moving at high speeds.

★ *G-R Type 1530-A Microflash provides an intense white light for single-flash photography of very rapidly moving objects — flash intensity is 20,000,000 beam candles — duration is only 2 millionths of a second*

★ *Power supply and trigger circuits are assembled in one metal case, lamp is in another — two sections lock together for complete protection of all controls and ease in transportation*

★ *Panel pushbutton initiates flash — alternative is to have flash tripped by noise or pressure wave associated with the action to be photographed; microphone and built-in amplifier are provided for such use*

★ *Additional jack is available for flashing from any simple external contactor — photoelectric cells, wire breaking under tension or impact, and many other easily-built devices will trip flash to suit the application*

★ *Conventional camera equipment is used*

★ *Accessories supplied include microphone with cable, tripod, spare pilot lamps and fuses, 2 spare flash lamps, and plug for connection to external-contactor trip jack*

★ *Dimensions are 24⅛ x 13¼ x 11¾ inches, overall — net weight is 72 pounds*

★ *Price:* **$640.00**

GENERAL RADIO Company

275 Massachusetts Avenue, Cambridge 39, Massachusetts, U. S. A.

90 West St. NEW YORK 6 920 S. Michigan Ave. CHICAGO 5 1000 N. Seward St. LOS ANGELES 38

Admittance Meters ☆ Coaxial Elements ☆ Decade Capacitors
Decade Inductors ☆ Decade Resistors ☆ Distortion Meters
Frequency Meters ☆ Frequency Standards ☆ Geiger Counters
Impedance Bridges ☆ Modulation Meters ☆ Oscillators
Variacs ☆ Light Meters ☆ Megohmmeters ☆ Motor Controls
Noise Meters ☆ Null Detectors ☆ Precision Capacitors
Pulse Generators ☆ Signal Generators ☆ Vibration Meters ☆ Stroboscopes ☆ Wave Filters
U-H-F Measuring Equipment ☆ V-T Voltmeters ☆ Wave Analyzers ☆ Polariscopes

Instruments by WESTON

Weston Model 1151
COURSE INDICATOR
— a combination Cross Pointer—Course Selector—Pictorial Heading—Ambiguity and Deviation Indicator. 2¾" dial opening.

Navigation instruments

Engine instruments

Power supply instruments

Communications instruments

Special purpose instruments

Test Equipment

WESTON Aircraft *Instruments*

Weston Electrical Instrument Corporation
614 Frelinghuysen Avenue, Newark 5, New Jersey

BOEING YB-52 STRATOFORTRESS 8-J57 jet engines

STURGESS REGULATORS

Sturgess Regulator, used in YB-52 jet engine throttle system

...out of sight...out of mind

BUILDERS of many famous airplanes, both military and commercial, have provided us with a fine, but mute, testimonial. When Sturgess Regulators are built into an aircraft, we rarely hear of them again.

You air men know that maximum performance and safety comes only when precise tension is maintained on both primary and secondary control systems, under *all* conditions at *all* times.

Sturgess Regulators are mechanical in operation and designed to maintain adequate control cable tension under all flight conditions at any altitude or temperature.

STURGESS REGULATORS compensate for natural structural deflection which might affect cable tension. Sturgess Regulators enable control systems using long cable runs to be rigged at lower tension, reducing the friction factor which decreases cable and pulley wear, improving plane's operating efficiency.

The regulator unit pictured above is the type used in regulating the cable tension in the throttle system on the 8-jet powered Boeing YB-52 Stratofortress.

Pacific Scientific Co. engineers are available to show you how Sturgess Regulators can best be adapted to your control systems.

PACIFIC SCIENTIFIC CO.
manufacturers
STURGESS REGULATORS,
SPEED-RIG QUICK CABLE DISCONNECT,
TENSIOMETERS, ACCELEROMETERS,
and HUMPHREY GYROS, LINEAR
POTENTIOMETERS *and* OTHER
GUIDANCE UNITS.

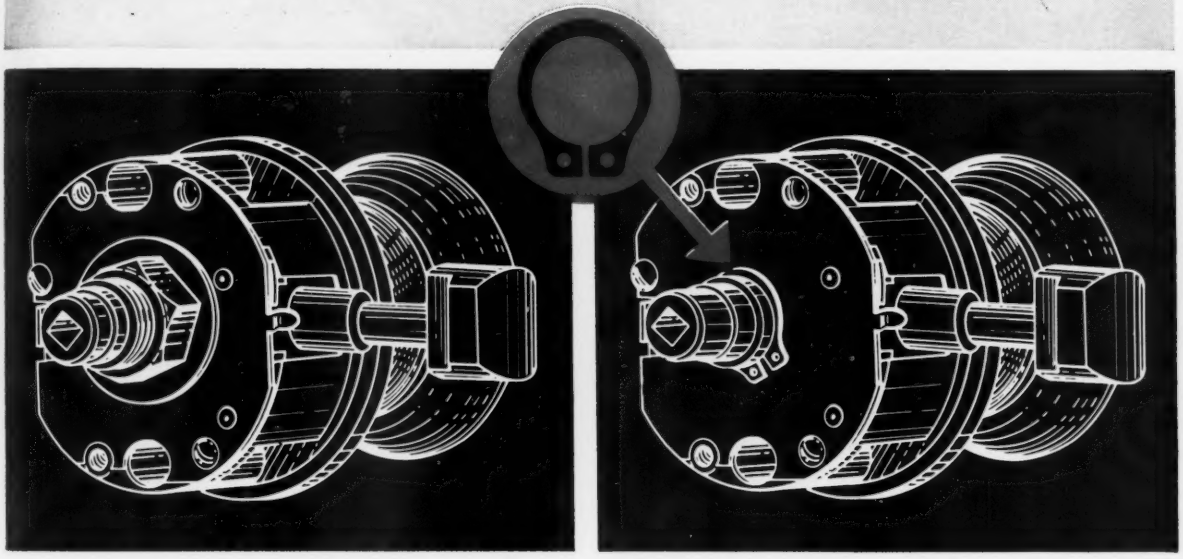
PACIFIC SCIENTIFIC ENGINEERING
"KNOW HOW" has been incorporated in the control system regulation of many famous military and commercial multi-engine planes. These men are available to assist you...write today or call the nearest office.

Pacific SCIENTIFIC CO.

LOS ANGELES, CALIF.
1430 Grande Vista Ave.
SAN FRANCISCO, CALIF.
25 Stillman Street
SEATTLE, WASHINGTON
1915 1st Ave. South
ARLINGTON, TEXAS
806 East Abram St.

EASTERN REPRESENTATIVE: Aero Engineering, Inc., 288 Old Country Road, Mineola L.I., New York · 2500 St. Paul St. Baltimore, Md. · 20 North Meridian St., Indianapolis, Ind. · AERO SALES ENGINEERING, Montreal A.M.F., P.Q., Canada

Waldes Truarc Ring Replaces Nut and Washer ...Cuts Costs $5.28 Per M...Speeds Assembly by 50%



OLD WAY. Main shaft required costly threading. Assembly was slowed by the double application of washer and nut and time-consuming tightening operation.

TRUARC WAY. Truarc Retaining Ring snaps quickly and simply over shaft. Lock assembly is secured in one fast operation. Virtually all play is eliminated from lock.

NEW DESIGN USING WALDES TRUARC RING PERMITTED THESE SAVINGS

OLD WAY

Cost of Nut	$10.00	per thousand
Cost of Washer	3.80	" "
Labor for Threading	2.00	" "
Assembly	3.00	" "
TOTAL	$18.80	

TRUARC WAY

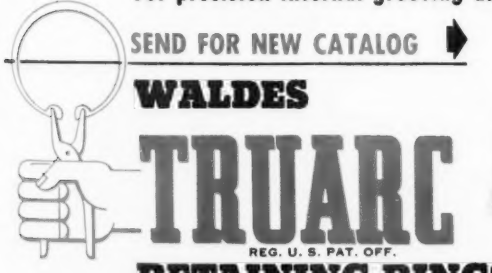
Cost of Truarc Ring and Grooving Operation	$11.52	per thousand
Assembly	2.00	" "
TOTAL	$13.52	

J. Chesler and Sons, Inc., Brooklyn, N.Y., manufacturers of the pre-assembled "Reddi-Mount" cylindrical lockset, uses a single Waldes Truarc Retaining Ring instead of an old fashioned nut and washer to secure the entire assembly of their lock. This new, improved fastening method enables Chesler to eliminate costly threading ... save money on material ... speed assembly time by 50% and produce an improved, more durable product.

You, too, can save money with Truarc Rings. Wherever you use machined shoulders, bolts, snap rings, cotter pins, there's a Waldes Truarc Retaining Ring designed to do a better, more economical job. Waldes Truarc Rings are precision-engineered ... quick and easy to assemble and disassemble.

Find out what Waldes Truarc Retaining Rings can do for you. Send your blueprints to Waldes Truarc engineers.

For precision internal grooving and undercutting... Waldes Truarc Grooving Tool



SEND FOR NEW CATALOG

WALDES TRUARC

REG. U. S. PAT. OFF.

RETAINING RINGS

WALDES KOHINOOR, INC., LONG ISLAND CITY 1, NEW YORK

WALDES TRUARC RETAINING RINGS AND PLIERS ARE PROTECTED BY ONE OR MORE OF THE FOLLOWING U. S. PATENTS: 2,382,947; 2,382,948; 2,416,852; 2,428,341; 2,439,765; 2,441,846; 2,455,165; 2,420,941; 2,483,380; 2,483,383; 2,487,802; 2,487,803; 2,491,306; 2,509,081; AND OTHER PATENTS PENDING.

AE-125

Waldes Kohinoor, Inc., 47-16 Austel Pl., L. I. C. 1, N. Y.

Please send me the new Waldes Truarc Retaining Ring catalog.

(Please print)

Name.....

Title .....

Company .....

Business Address.....

City..... *Zone*..... *State*.....

LIBRARY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

A Salute to

FIFTY YEARS of POWERED FLIGHT

from

UNITED STATES AIRCRAFT INSURANCE GROUP

and its Managers

Aetna Casualty & Surety Co.
Aetna Insurance Company
Agricultural Insurance Co.
American Employers' Ins. Co.
American Surety Co. of N. Y.
Atlantic Fire Ins. Company
Automobile Insurance Co.
Bankers & Shippers Ins. Co. of N. Y.
Birmingham Fire Ins. Co. of Penna.
Boston Insurance Company
Camden Fire Ins. Association
Central States Fire Ins. Co.
Century Indemnity Company
Charter Oak Fire Ins. Co.
Citizens Ins. Co. of N. J.
Connecticut Fire Ins. Co.
Empire State Ins. Company
Employers' Fire Ins. Co.
Employers' Liability Assurance Corp., Ltd.
Equitable Fire & Marine Ins. Co.
Fire Association of Phila.
Granite State Fire Ins. Co.
Hartford Accident & Indemnity Co.
Hartford Fire Ins. Company
Jersey Ins. Co. of N. Y.
Maryland Casualty Company
Massachusetts Bonding & Ins. Co.
Mercury Insurance Co.
Michigan Fire & Marine Ins. Co.
Minneapolis Fire & Marine Ins. Co.
National Union Fire Ins. Co.
New Amsterdam Casualty Co.
New England Ins. Company
New Hampshire Fire Ins. Co.
New York Underwriters Ins. Co.
North River Insurance Co.
Northwestern Fire & Marine Ins. Co.
Old Colony Insurance Co.
Pacific Fire Insurance Co.
Phoenix Insurance Company
Providence Washington Ins. Co.
Reliance Ins. Co. of Phila.
Saint Paul Fire & Marine Ins. Co.
Southern Fire Ins. Company
Springfield Fire & Marine Ins. Co.
Standard Accident Ins. Co.
Standard Fire Ins. Company
Standard Ins. Co. of N. Y.
Travelers Fire Ins. Company
Travelers Indemnity Company
Travelers Insurance Company
Twin City Fire Ins. Company
United States Casualty Co.
United States Fidelity & Guaranty Co.
United States Fire Ins. Co.
Westchester Fire Ins. Co.
World Fire & Marine Ins. Co.

1928 25th Anniversary 1953 USAIG

UNITED STATES AVIATION UNDERWRITERS, INC.

Managers

80 John Street, New York 38, N. Y.

CHICAGO • ATLANTA • LOS ANGELES • KANSAS CITY • DALLAS • SAN FRANCISCO

BLIND FLYING...

another Sperry first... 1929

1929 In covered cockpit of his NY-2, Lieutenant "Jimmy" Doolittle, using Gyro-Horizon and Directional Gyro makes first "blind" flight including take-off and landing. Lieutenant Ben Kelsey acts as check pilot.

"Blind" flying has an interesting history. For years many people had flown "blind" on occasion through clouds. And in 1926, William C. Ocker proved man's physiological inability to fly "blind" without instruments. His experiments, based on the Sperry-developed Turn and Bank Indicator, helped pilots understand and use flight instruments. The era of dependable all-weather flying did not begin, however, until Lieutenant "Jimmy" Doolittle made his historic "blind" flight in 1929. With the aid of two new Sperry instruments—an artificial horizon and a gyroscopic directional indicator—he led the way to dependable all-weather flying.

TODAY, AS THEN, SPERRY LEADS THE WAY

Twenty-four years have passed since the Doolittle flight. In those years Sperry has pioneered in development after development, utilizing electronics to make earlier instruments more precise, and to provide still greater mastery of the elements. With the Sperry Zero Reader* Flight Director, for example, military pilots now manually fly and navigate at supersonic speeds with accuracy and precision approaching that of automatic flight—and, with Sperry armament can intercept and destroy enemy aircraft unseen by human eyes.

*T. M. REG. U. S. PAT. OFF.

1932 Captain A. F. Hegenberger in Douglas BT-2A makes first solo "blind" flight and landing at Wright Field, with Sperry Gyro-Horizon and Directional Gyro.

1936 Air Corps Major Ira Eaker, left, makes first transcontinental "blind" flight—and alone—in BT-2A, equipped with Sperry Gyro-Horizon and Directional Gyro. Major William E. Kepner pilots escort plane.

1941-45 Sperry flight instruments enable U. S. Navy and Marine fliers to operate from carriers, day or night. Airborne radar helps pilots locate enemy aircraft and submarines.

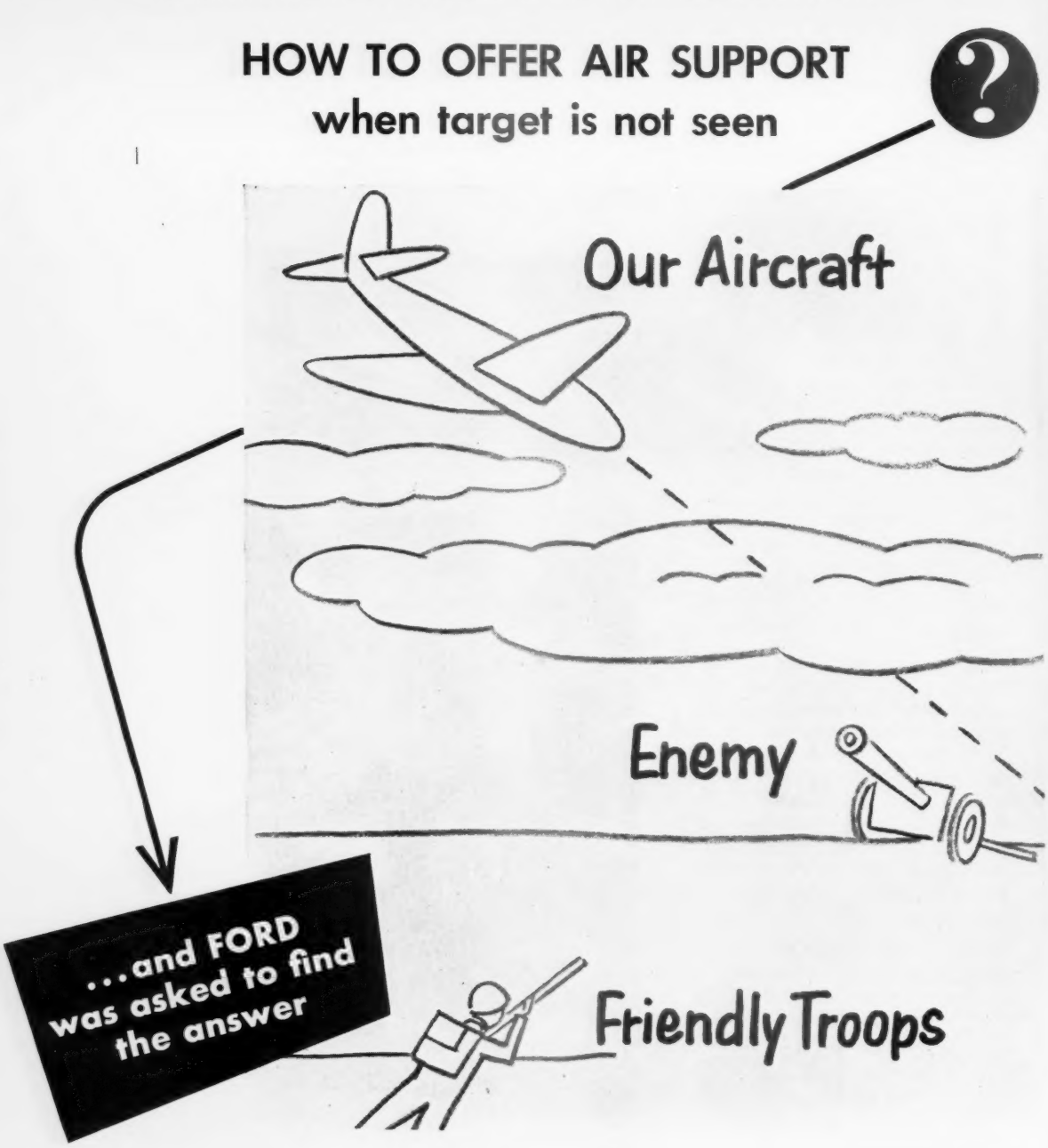
1953 The Sperry Zero Reader Flight Director in conjunction with radar aids interception at high altitudes, day or night.

SPERRY GYROSCOPE COMPANY
DIVISION OF THE SPERRY CORPORATION
GREAT NECK, NEW YORK

PROGRESS 50TH ANNIVERSARY OF POWERED FLIGHT SECURITY

One of a series of advertisements commemorating the Fiftieth Anniversary of Powered Flight.

HOW TO OFFER AIR SUPPORT
when target is not seen



Blinding rain! Darkest night! Obscuring clouds! One of these conditions . . . or all three combined . . . deter planes from seeking out and destroying enemy strong points in support of friendly front line troops. That's why the Ford Instrument Company was called in by the Navy to design and build compact, airborne equipment to do this job.

This is typical of the problems that Ford has been given by the Armed Forces since 1915. For from the vast engineering and production facilities of the Ford Instrument Company, come the mechanical, hydraulic, electro-mechanical, magnetic and electronic instruments that bring us our "tomorrows" today. Control problems of both Industry and the Military are Ford specialties.

8

You can see why a job with Ford Instrument offers young engineers a challenge. If you can qualify, there may be a spot for you in automatic control development at Ford. Write for brochure about products or job opportunities. State your preference.

FORD

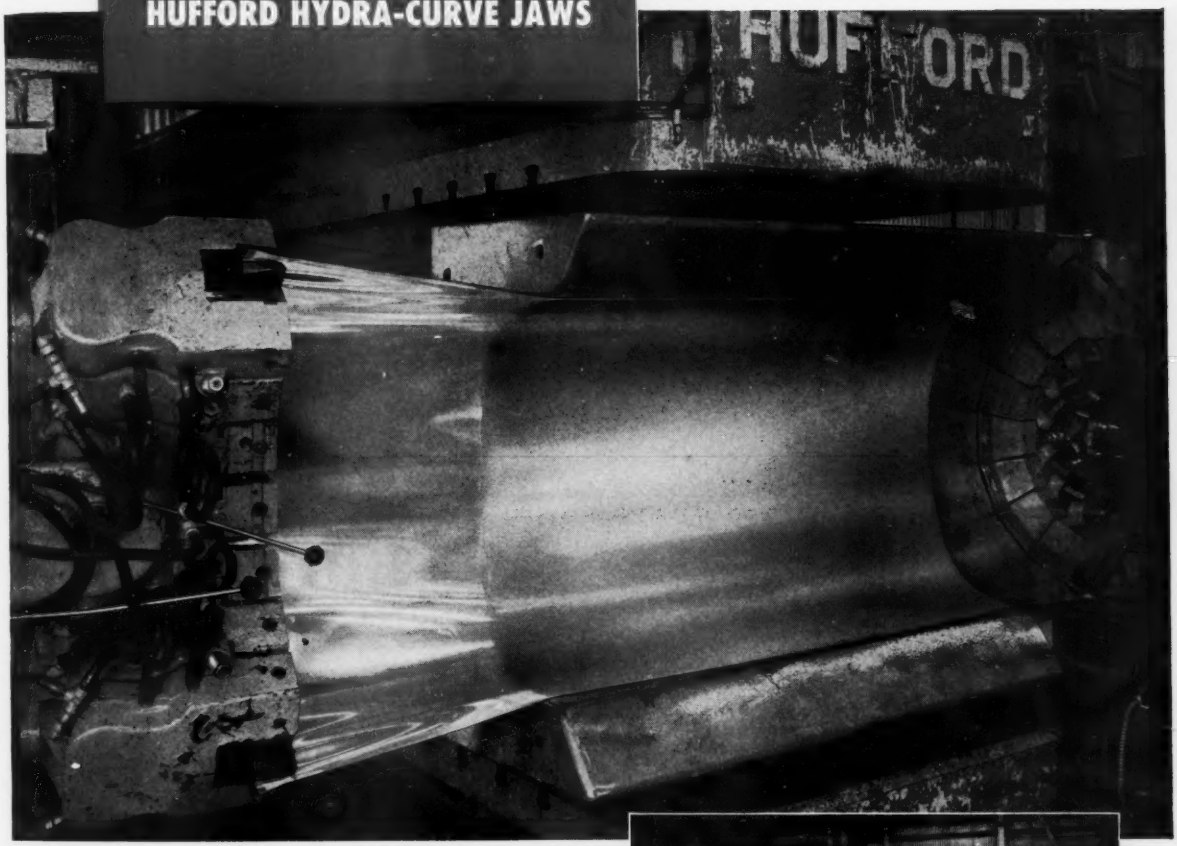
FORD INSTRUMENT COMPANY
DIVISION OF THE SPERRY CORPORATION
31-10 Thomson Avenue, Long Island City 1, N. Y.

"Bath-Tub" Deep!

THIS SKIN IS STRETCH-WRAP FORMED EASIER—FASTER—CHEAPER WITH THE NEW

HUFFORD HYDRA-CURVE JAWS

Here's the latest Hufford development that simplifies stretch-wrap forming of deep concavities or convexities. By pre-curving sheets to approximate cross sectional die contour these new HYDRA-CURVE JAWS bring many advantages:



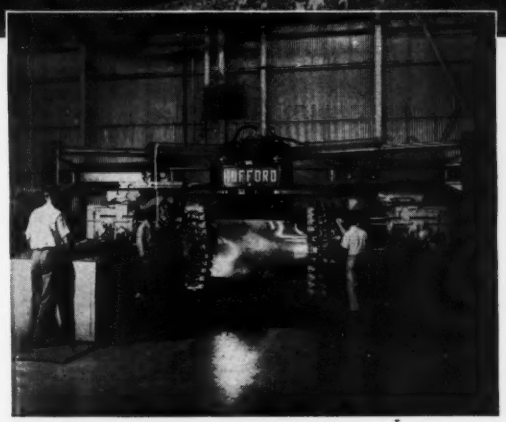
LESS STOCK USED—Vertical die curves no longer need to be *stretched* into the workpiece. Less stretching results in lower stressing. On deep curvatures this means *less stock required between die ends and jaws.* Result: Up to 30% savings in material.

DOLLAR SAVINGS—One manufacturer reports material savings of $335 per day, besides faster, easier forming and more accurate skin fits, which again cut costs.

LESS WRINKLING—No need to stretch wrinkles *out* of the workpiece. Pre-curving eliminates most wrinkling *before it starts.*

SAVES FURNACE HOURS—Many parts are now formed directly from material in the "ST" condition.

DIE COSTS CUT—Time consuming dish-outs in dies—to help reduce transitional stresses—are no longer necessary.



Once again, here's proof that the *BEST* in stretch-wrap forming comes *FIRST* from HUFFORD! Ask for facts.

HUFFORD
Machine Works Inc.
EL SEGUNDO, CALIFORNIA

Manufacturers of

PRECISION HYDRAULIC STRAIGHTENING PRESSES
HYDRAULIC METAL FORMING BULLDOZERS • HYDRAULIC STRETCH-LEVELING TABLES
HYDRAULIC STRETCH-WRAP FORMING MACHINES
PORTABLE HYDRAULIC ELEVATORS • HYDRAULIC COMPACTION PRESSES
CUSTOM-MADE HYDRAULIC MACHINE TOOLS AND ACCESSORIES

87 Westinghouse products
bring tomorrow's aircraft
One step closer

da Vinci's concept never envisioned the supersonic age . . . or the complexity of modern aircraft. But in this "Span of Flight", aviation designers have telescoped centuries of normal evolution into fifty short years of accelerated progress. 87 Westinghouse products have helped make this possible. Yes, it's true, between Magamps . . . turbojets . . . fire control radar . . . electrical systems . . . aircraft motors and Micarta® there are 87 different Westinghouse products helping the aviation industry bring tomorrow's aircraft—One Step Closer.

This scope of Westinghouse in aviation is important to you. Not only the particular advancements highlighted in this "One Step Closer" series, but any one of the 87 products can become a solution to your subsystem or component parts problem. Coming from the engineering and productive skills of twenty-three divisions, they are part of a continuing research and development program dedicated to improving the capability and potential of tomorrow's combat and commercial aircraft.

SEND FOR "SPAN OF FLIGHT"

This special photographic document was prepared to emphasize this Westinghouse ability and interest in helping you achieve the goal of tomorrow's aircraft. It exemplifies the "Span of Flight" from Leonardo da Vinci's 15th century "flying machine with a man" to a current NACA concept of tomorrow's aircraft. It is yours —in beautiful sepia, without copy and suitable for framing—for telling us just how many Westinghouse aviation products are known to you. Check them in the coupon below . . . your "Span of Flight" will soon be on its way. J-91012

YOU CAN BE SURE...IF IT'S

Westinghouse

WESTINGHOUSE ELECTRIC CORPORATION
3 Gateway Center, P. O. Box 868
Pittsburgh 30, Pa.

I know Westinghouse makes these products:

- ☐ Turbojet engines.
- ☐ Autopilots, radar and fire control systems.
- ☐ Communications equipment, air-borne and ground.
- ☐ Aircraft electrical systems, a-c and d-c.
- ☐ Air-borne instruments, transformers and rectifiers.
- ☐ Gyro-motors and temperature control panels.
- ☐ Generating equipment, circuit breakers, contactors.
- ☐ Aircraft motors, actuators and hoists.
- ☐ Electronic tubes and Magamps.
- ☐ Wind-tunnel drives and Micarta.
- ☐ Airport lighting and wind-indicating equipment.

Please send me "Span of Flight", without copy and suitable for framing.

Name_____ Title_____

Company_____

Address_____

City & State_____

DRAWING BY LEONARDO DA VINCI, "FLYING MACHINE WITH A MAN", COURTESY REYNAL AND HITCHCOK, HARCOURT BRACE AND COMPANY.

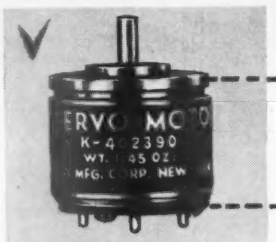
SCALE NACA MODEL, COURTESY LEWIS FLIGHT PROPULSION LABORATORY, CLEVELAND, OHIO

DEPARTMENT OF TECHNOLOGY
BUREAU OF PUBLIC LIBRARIES

TYPICAL CHARACTERISTICS

MECHANICAL DATA		ELECTRICAL DATA	
Weight	1.45 oz.	No load speed	6,500 RPM
Rotor inertia	.46 gm-cm²	Stall torque	.3 oz.-in.
Theoretical acceleration	49,000 RAD/SEC²	Maximum output	.490 W.
		Single phasing	None

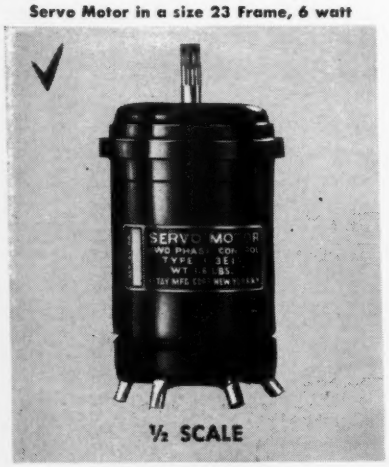
DATA AT STALL	FIXED PHASE	CONTROL PHASE
Voltage (volts)	26	26
Frequency (cycles)	400	400
Current (ma.)	166	166
Power input (watts)	3.1	3.1
Power factor	.63	.63
R—ohms	98.5	98.5
X—ohms	123	123
Z—ohms	157	157



Servo Motor the size of a Penny

Ketay's Experience helps you

Servo Motor in a size 23 Frame, 6 watt



TYPICAL CHARACTERISTICS

MECHANICAL DATA		ELECTRICAL DATA	
Weight	1.6 lbs.	No load speed	3,500 RPM
Rotor inertia	20.0 gm-cm²	Stall torque	7.5 oz.-in.
Theoretical acceleration	26,500 RAD/SEC²	Maximum output	6.0 W.
		Single phasing	None

DATA AT STALL	FIXED PHASE	CONTROL PHASE Series	CONTROL PHASE Parallel
Voltage (volts)	115	115	57.5
Frequency (cycles)	60	60	60
Current (ma.)	175	175	350
Power input (watts)	14.0	14.0	14.0
Power factor	0.70	0.70	0.70
R—ohms	460	460	115
X—ohms	470	470	117
Z—ohms	660	660	164

Also for 115V or 230V operation on control phase.

Check these Servo Motors against your needs

Ketay offers a complete line of high precision **SYNCHROS, SERVO MOTORS and RESOLVERS.**

Ketay's experience also includes: automatic control devices for use in fire control and missile systems; computers and simulators; amplifiers; marine inter-communication equipment; remote indicators such as ship course indicators, drive angle indicators and salinity indicators; and automatic control systems.

Mail coupon today for bulletin containing specifications on 100 types of Synchros, Servo Motors and Resolvers.

Servo Motor in a size 15 Frame, 60 cycle, 115 volt

TYPICAL CHARACTERISTICS

MECHANICAL DATA		ELECTRICAL DATA	
Weight	7.3 oz.	No load speed	3,300 RPM
Rotor inertia	3.03 gm-cm²	Stall torque	1.45 oz.-in.
Theoretical acceleration	33,800 RAD/SEC²	Maximum output	1.23 W.
		Single phasing	None

DATA AT STALL	FIXED PHASE	CONTROL PHASE Series	CONTROL PHASE Parallel
Voltage (volts)	115	115	57.5
Frequency (cycles)	60	60	60
Current (ma.)	53	53	106
Power input (watts)	5.0	5.0	5.0
Power factor	.82	.82	.82
R—ohms	1780	1780	445
X—ohms	1240	1240	310
Z—ohms	2170	2170	542

Ketay

DESIGN
DEVELOPMENT
MANUFACTURE
... of precision instruments components, systems.

MANUFACTURING CORPORATION

Executive Offices
555 Broadway
New York 12, N. Y.

West Coast Sales
12833 Simms Avenue
Hawthorne, California

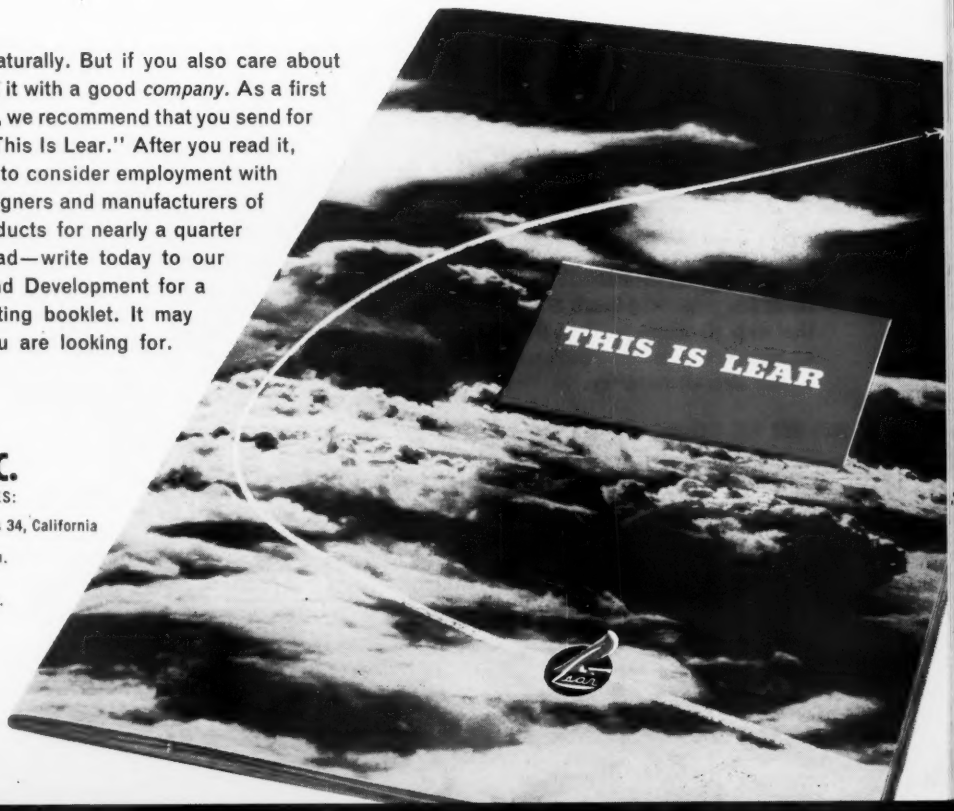
New York Division • Kinetix Instrument Division • Pacific Division
Electronic Instrument Division • Research & Development Division

Ketay Manufacturing Corp. H
555 Broadway, New York 12, N. Y.

NAME.....
POSITION.....
COMPANY.....
ADDRESS.....
CITY.....STATE.....
Send data on.....
My current projects are.....

Engineers–look before you leap!

You want a good job, naturally. But if you also care about your future, you will seek it with a good *company*. As a first step in the right direction, we recommend that you send for a copy of the booklet, "This Is Lear." After you read it, we believe you will want to consider employment with Lear, Incorporated—designers and manufacturers of quality aeronautical products for nearly a quarter of a century. Look ahead—write today to our Director of Research and Development for a free copy of this interesting booklet. It may be just the "break" you are looking for.



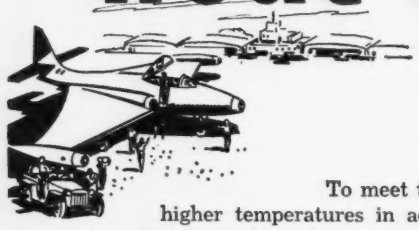
LEAR, INC.
EXECUTIVE OFFICES:
3171 South Bundy Dr., Los Angeles 34, California

GRAND RAPIDS, MICH.
ELYRIA, OHIO
LOS ANGELES, CALIF.

for today's "hotter" jets, South Wind presents...

new lightweight, thinwall

stainless steel heat exchangers*



To meet the challenge of higher temperatures in advanced jet engines, South Wind has developed new lightweight, thinwall stainless steel heat exchangers. These heat exchangers fully comply with the rigid specifications set up by airframe and engine manufacturers, as well as the makers of air cycle cooling packages.

In addition to stainless steel, thinwall aluminum heat exchangers also are being designed and fabricated at South Wind for many different applications. Heat transfer from air-to-air, liquid-to-liquid, and air-to-liquid is being achieved effectively with the new South Wind heat exchangers, which utilize either the tube bundle or the plate and fin types of design . . . whichever the job requires.

*Illustrated here is a thinwall stainless steel tube bundle heat exchanger

For Aircraft Heating OR Cooling

Pioneers in the field of aircraft heat exchange equipment for providing heat, South Wind has now put that experience to work in the development of heat exchangers for cooling purposes . . . another service to the aircraft industry.

"Can Do!"

Whatever *your* need in heat transfer equipment, South Wind's experienced engineering staff will be glad to consult with you. For information, write Stewart-Warner Corporation, South Wind Division, 1514 Drover Street, Indianapolis 7, Indiana.

South Wind

A PRODUCT OF SW STEWART WARNER

AIRCRAFT HEATERS
HEAT EXCHANGE EQUIPMENT
INERT GAS GENERATORS

For the Answer to Your Insulation Problem

Look Through *this* Line...

● Can't guarantee that the Varflex Line will solve every insulation problem. But . . . Many's the problem—large, small, unusual—that Varflex Electrical Sleeving or Tubing has solved. The Varflex range of application is vast—chances are you'll find the solution to your Electrical insulating problem somewhere in the Varflex line.

- **VARGLAS SILICONE.** That's the insulating sleeving and tubing—pioneered by Varflex—that takes temperatures ranging from 500° F above to 85° F below in its efficient, resistant stride. Lead wire and treated cord too.
- **VARGLAS TUBING IMPREGNATED WITH GENERAL ELECTRIC PERMAFIL.** Tough, flexible, heat-resistant—available in coils. Premium tubing at a reasonable price.
- **VARGLAS SLEEVING AND TUBING.** Numerous types and grades—including synthetic treated, varnished, lacquered, saturated, litewall and others.
- **VARGLAS NON-FRAY SLEEVING.** Three types—may be subjected to temperatures up to 1200° F—for applications where dielectric requirements are not primary.
- **VARFLO TUBING AND SLEEVING.** New, low-priced — for applications where unusually high temperatures are not a factor. A real economy line, this.
- **VARFLEX COTTON TUBING AND SLEEVING.** Varnish or lacquer impregnants — for applications where Fiberglas products are not required.
- **SYNTHOLVAR EXTRUDED PLASTIC TUBING.** Low temperature flexibility—high dielectric and tensile strength—made from a standard formulation of vinyl polymers.

SAMPLES? All you want with our compliments. For free folder of our complete line, just clip and mail this coupon.

VARFLEX CORPORATION

MAKERS OF ELECTRICAL INSULATING TUBING AND SLEEVING

VARFLEX Corporation, 311 Jay St., Rome, N. Y.

Please send me information as well as free samples of your electrical Sleeving and Tubing.

I am particularly interested in samples suitable for.....

.....

Name.....

Company.....

Street.....

City.....Zone.....State.....

DEPARTMENT OF TECHNOLOGY BUFFALO PUBLIC LIBRARY

BARBER COLMAN

Aircraft Controls

assure complete comfort for passengers and crews wherever today's airliners fly...across all continents, through all climate changes!

BARBER-COLMAN TEMPERATURE CONTROL SYSTEMS ARE ON AIRCRAFT OF ALL THESE AIRLINES*

Aero O/Y
Aerolineas Argentinas
Aerolinee Italiana Internazionali
Aeronaves de Mexico
Aerovias Ecuatorians
Avianca
Aerovias Venezolanas
Aigle Azur
Air France
Air-India International, Ltd.
Alaska Airlines
American Airlines
Australian National
Avensa
Braatens Safe
Braniff International Airways
Brazilian International
British Commonwealth Pacific Airlines
British Overseas Airways Corp.
California Central Airlines
Canadian Pacific Airlines
Capital Airlines
Central African Airways
Coastal Cargo
Compania Cubana de Aviacion
Compania Mexicana de Aviacion
Continental Airlines
Delta C & S Airlines
Eastern Airlines
El Al Israel Airlines
Ethiopian Airlines
Flying Tigers
Garuda Indonesian Airways
Hawaiian Airlines
Hellenic Overseas Airways
Iberia
Japan Air Lines
Jugoslov
KLM
Linea Aerea Nacional de Chile
Linea Aeropostal Venezolana
Linee Aeree Italiane
Lufthansa
National Airlines
North American Airlines
North Central Airlines
Northeast Airlines
Northern Consolidated Airlines
Northwest Airlines
Orient Airways
Pakistan Aviation Ltd.
Panair do Brasil
Pan American World Airways
Panagra
Philippine Airlines
Qantas Empire Airways
Real
Reeve Aleutian Airways
Scandinavian Airlines System
Seaboard and Western Airlines
Servicos Aereos Cruzeiro do Sul
Slick Airways
Sabena
South African Airways
Southwest Airways
Swiss Air Transport
TAE National Greek Airlines
TAI
Thai Airways Co., Ltd.
Trans-Australian Airlines
Trans Canada Airlines
Transportes Aeros Portuguese
Trans World Airlines
United Air Lines
Varig
Viacao Aerea Sao Paulo
Western Airlines

*On aircraft flying or on order

Wherever in the world you fly on an airliner equipped with a Barber-Colman temperature control system, you travel comfortably.

For example, from take-off in cold northern latitudes to landing at a distant desert field, the selected cabin temperature is carefully held to close limits. Or on a nonstop flight from California to New York . . . over various climate zones, climbing and letting down through changing temperature levels . . . quick, correct air conditioning adjustments are automatically made.

That's why you find Barber-Colman temperature control systems on so many airliners operating throughout the world. These precise-operating systems are the result of nearly 20 years' experience in cabin comfort control. In fact, the early DC-1 was Barber-Colman equipped.

Today Barber-Colman Company offers complete coverage of the automatic temperature control field: Cycling . . . full proportional . . . Micropulse . . . and electronic—for commercial, military and executive aircraft. All are individually engineered to meet the exact needs of the aircraft and the operations to which they will be assigned.

Whenever you have need for highly dependable temperature controls, consult Barber-Colman engineers for the system best suited to your particular application.

FREE BOOKLET

Informative new illustrated booklet on all Barber-Colman Aircraft Controls. Yours for the asking. See the Barber-Colman engineering sales office in Los Angeles, Seattle, Chicago, Baltimore, New York or Montreal. Or write direct to Barber-Colman Company, Dept. L, 1424 Rock Street, Rockford, Illinois.

BARBER COLMAN Aircraft Controls

Aircraft Controls • Automatic Controls • Industrial Instruments • Small Motors • Air Distribution Products • OVERdoors and Operators • Molded Products • Metal Cutting Tools • Machine Tools • Textile Machinery

Navy's newest anti-sub weapon — the Bell Aircraft XHSL-1. It features high rotor disc loadings for greater range and speed.

THE MASTS FOR BELL'S NEW XHSL-1 . . . . WERE MACHINED AT NATIONAL FORGE

Machined from drawn tubing, these helicopter masts are heat treated, tested, machined and plated complete in our plant ready for installation. The application demands the highest quality in metallurgical and physical properties. Maintenance of the exacting machining tolerances and acceptance by rigid inspection insure interchangeability.

The special skills required to finish machine such mechanical components have been developed at National Forge through many years of close co-operation with the aircraft industry. New tools are constantly added to meet the requirements of this rapidly growing part of our business.

Your problems of finished parts for aircraft or commercial use can be solved at National Forge. We give complete service using our forgings or purchased material when necessary to produce finished single parts or assemblies.

We will be glad to consider any job you have . . . and our experience in machining and metallurgical problems is available to assist you if you desire.

NF

National Forge AND ORDNANCE COMPANY

Irvine, Warren County, Pennsylvania

STEEL MAKERS ☆ FORGESMITHS
HEAT TREATERS ☆ MACHINISTS

NEW PROTECTIVE COATING CHEMICAL FOR ALUMINUM

ALODIZING

Alodizing with "Alodine,"* a new technique in the protective coating of aluminum, was made available for production-scale use in 1946. Since that time Alodizing has largely supplanted the more elaborate, costly and time-consuming anodic treatments in the aircraft and other industries.

Continuous and successful industrial use has clearly demonstrated the simplicity and economy of the Alodizing process as well as the effectiveness of the "Alodine" amorphous coatings, particularly as a base for paint. In fact, the paint-bond that Alodized aluminum provides has been found to be superior to that possible with chromic acid anodizing.

The corrosion-resistance of unpainted aluminum Alodized with "Alodine" Nos. 100 or 300 is excellent, easily meeting the requirements of Specification MIL-C-5541. However, a need for protection of unpainted aluminum, even better than that obtained with chromic acid anodizing, has long been recognized.

NEW IMPROVED "ALODINE" DEVELOPED By ACP RESEARCH CHEMISTS

Several years of intensive research have now led to a new type of "Alodine," designated as "Alodine" No. 1200. This new protective coating chemical forms an amorphous mixed metallic oxide coating of low dielectric resistance that provides unusually high corrosion-resistance for unpainted aluminum. In addition, it forms an excellent paint bond that approaches closely the high quality obtained with the earlier types of "Alodine."

After having been tested for conformance with Specification MIL-C-5541, "Alodine" No. 1200 is now about to go into production.

PROCESS DETAILS

"Alodine" No. 1200 is the only essential chemical needed to prepare the coating bath and the final rinse bath. One of its unique features is that it can be used in tanks in an immersion process, or, in a multi-stage power washer in a spray process, or, with a slight adjustment of pH, with brush or portable spray equipment in a manual process. This means that even where the simple production equipment is not available, or where touching up of damaged coatings previously Alodized or anodized is required, excellent protection and paint bonding can still be obtained with practically no equipment.

All three methods of application easily meet the requirements of Specification MIL-C-5541.

Process sequence for all three methods of application is the same as for other standard grades of "Alodine" such as Nos. 100, 300, and 600, viz.: 1. Pre-cleaning. 2. Rinsing. 3. Alodizing. 4. Rinsing. 5. Acidulated rinsing. 6. Drying.

Coating time in an immersion process ranges from 2 to 8 minutes and in a mechanized spray process is about 30 seconds. "Alodine" No. 1200 baths are operated at room temperatures (70° to 100°F.) and heating is required only if the bath has gotten cold after a "down" period.

RECOMMENDED USES FOR "ALODINE" No. 1200

"Alodine" No. 1200 is specifically recommended for coating wrought products that are not to be painted or are to be only partially painted; and for coating casting and forging alloys whether or not these are to be painted. "Alodine" Nos. 100 and 300 are still recommended for coating wrought products such as venetian blind slats, awnings, etc., that are invariably painted.

RESULTS OF TENSILE TESTS

This new "Alodine" not only retards visible corrosion and pitting, but as shown in the table below, the loss of ductility with "Alodine" No. 1200, both brush and dip, after 1000 hours salt spray was less than for chromic acid anodizing after 250 hours, and for "Alodine" No. 100 and a conventional chromate treatment after 168 hours exposure.

PROCESS	SALT SPRAY EXPOSURE	COMPLIANCE WITH TENSILE REQUIREMENTS OF MIL-C-5541
CHROMIC ACID ANODIZING	168 hrs.	passes
	250 hrs.	passes
	500 hrs.	fails
	1000 hrs.	fails
BRUSH "ALODINE" No. 1200	168 hrs.	passes
	250 hrs.	passes
	500 hrs.	passes
	1000 hrs.	passes
DIP "ALODINE" No. 1200	168 hrs.	passes
	250 hrs.	passes
	500 hrs.	passes
	1000 hrs.	passes
DIP "ALODINE" No. 100	168 hrs.	passes
	250 hrs.	fails
	500 hrs.	fails
	1000 hrs.	fails
CONVENTIONAL CHROMATE TREATMENT	168 hrs.	passes
	250 hrs.	fails
	500 hrs.	fails
	1000 hrs.	fails

*"Alodine" Trade Mark Reg. U. S. Pat. Off.

CHEMICALS ACP PROCESSES

AMERICAN CHEMICAL PAINT COMPANY

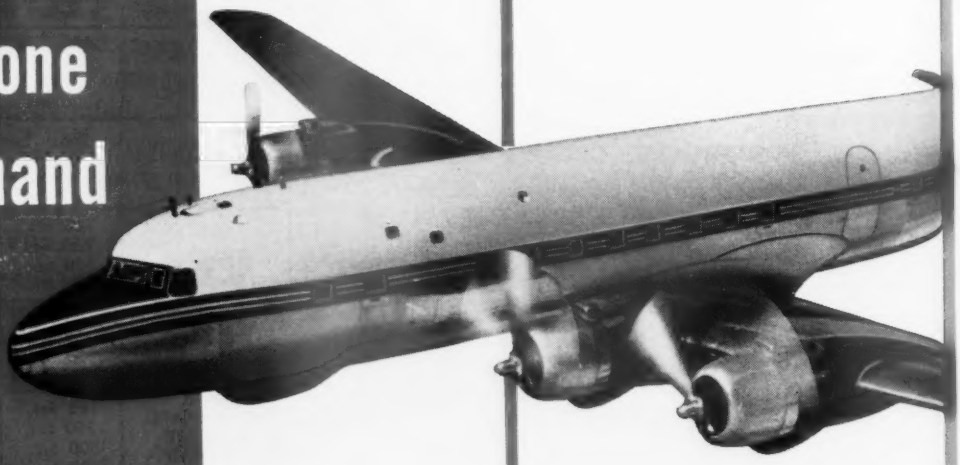
General Offices: Ambler, Penna.

Detroit, Michigan Niles, California Windsor, Ontario

gears you can hold in one hand

...are vitally important on this air giant

Midgets in size—giants in service—these precision gears were developed by Foote Bros. for this mighty, new Douglas Air Liner. Foote Bros. are today engineering and producing gears and mechanical drives of extreme precision for many of the nation's largest aircraft and aircraft engine manufacturers.



This trade mark stands for the finest in industrial gearing

FOOTE BROS. Duti-Rated LIFETIME GEARING

FOOTE BROS.

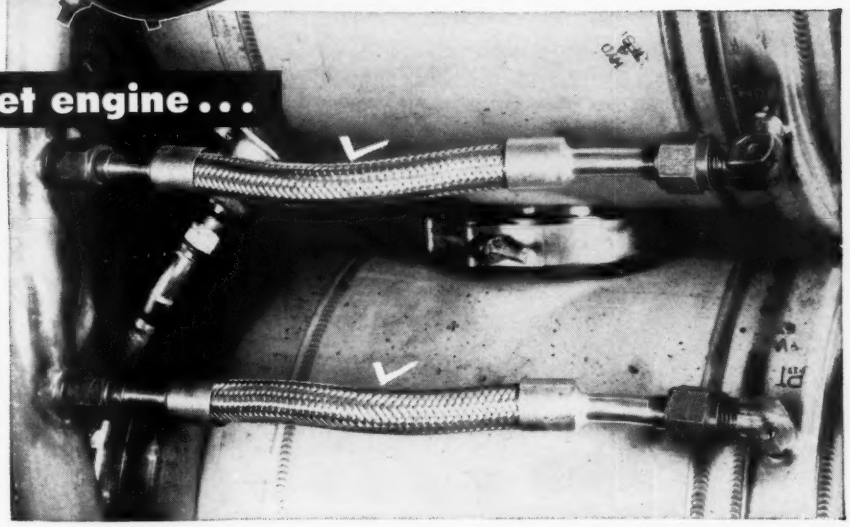
Better Power Transmission Through Better Gears

FOOTE BROS. GEAR AND MACHINE CORP. • 4545 S. WESTERN BLVD. • CHICAGO 9, ILL.

in a transport heater . . .

300,000 B.T.U. heater manufactured by Surface Combustion Corp. for Douglas DC-6A, DC-6B and DC-7 models. The Rex-Flex units house the spark plug assembly and serve to eliminate vibration and correct for misalignment.

or a fighter's jet engine . . .



⅜" I.D. Rex Flex hose is used in the water injection system of this General Electric Co. J-47 jet engine manufactured by the Studebaker Corporation. It absorbs axial and lateral motion and vibration at pressures to 600 psi and temperatures to 500° F.

Make flexible connections secure with REX-FLEX Stainless Steel Hose

IN the many critical connections in any aircraft or engine where flexibility and rugged durability must be combined, it will pay you to rely on Flexonics engineering skill and manufacturing know-how. As the pioneer manufacturer of stainless steel flexible metal hose, bellows, ducting and connectors, Flexonics Corporation has grown up with the modern aircraft industry. Your problems are our problems. For specific recommendations on any flexible connection problem, see your local Flexonics sales engineer or send an outline of your requirements.

Flexonics *Corporation*

AIRCRAFT DIVISION
1309 S. THIRD AVENUE · MAYWOOD, ILLINOIS

FORMERLY CHICAGO METAL HOSE CORPORATION
In Canada: Flexonics Corporation of Canada, Ltd., Brampton, Ontario

Flexon identifies products of Flexonics Corporation that have served industry for over 50 years.

Flexible metal hose

Expansion joints

Aircraft components

Metallic bellows

The things that count are on our side. Our aircraft are as good as the competitive system that produces them. Our pilots are as good as the freedom they protect. And wherever they fly, these men and these aircraft, an Airborne product flies with them.

AIRBORNE

ACCESSORIES CORPORATION

1414 Chestnut Avenue
Hillside 5, New Jersey

MANUFACTURERS OF ELECTROMECHANICAL ACTUATORS FOR THE AVIATION INDUSTRY

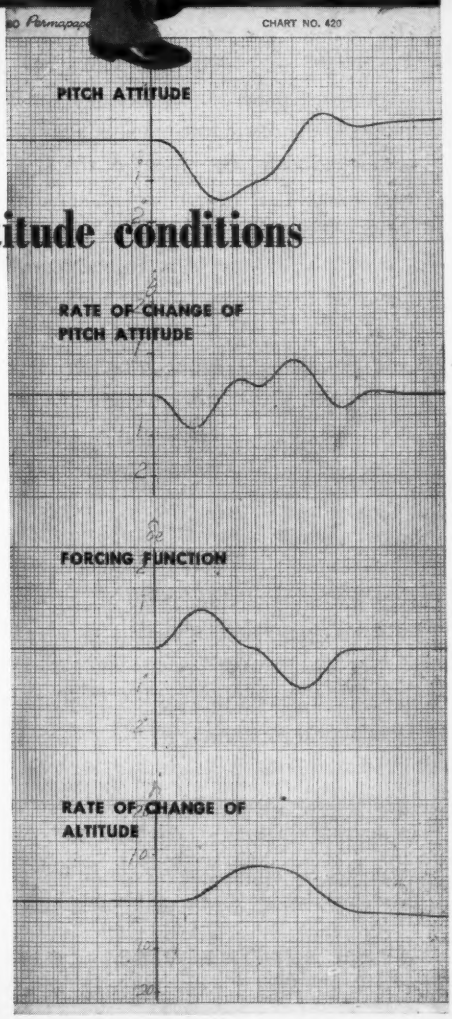
Four-channel recording correlates simulated jet bomber airspeed and altitude conditions

At Eclipse-Pioneer, engineers make good use of Sanborn 4-channel recording systems in conjunction with high precision analogue computers to establish performance criteria for automatic flight systems and components.

At other laboratories Sanborn Systems are being used to record such phenomena as: stress, strain, pressure, displacement, thickness, velocity, acceleration, current, voltage, temperature, torque, light, flow, force, load, position, rpm, radiation and tension.

SANBORN OSCILLOGRAPH RECORDING SYSTEMS HAVE MANY APPLICATIONS. They are used in a great many different fields where accurate and permanent graphic registration of almost any electrical phenomena (whose frequency range is zero to 100 cycles per second) is required.

Sanborn Systems are widely used because of the availability and ready interchangeability of amplifiers and preamplifiers, as well as such Sanborn advantages as: inkless recording in true rectangular coordinates, high torque movement, time and code markers and wide choice of paper speeds. In addition, a basic choice of systems, 1-, 2-, and 4-channels, provides a system to fulfill almost any laboratory requirements.



WRITE FOR CATALOG

Sanborn Company
INDUSTRIAL DIVISION
CAMBRIDGE 39, MASSACHUSETTS, U.S.A.

RYAN FIREBEE

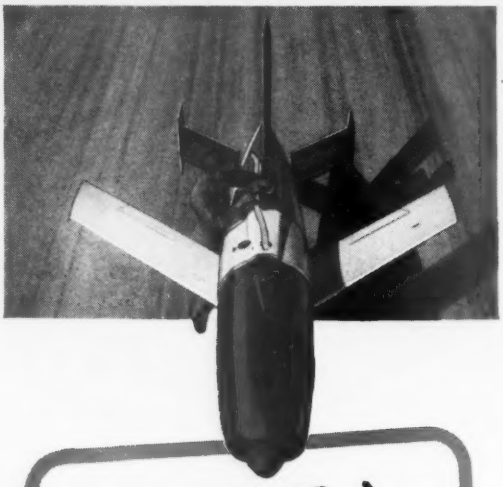
...it lives fast and dangerously!

To keep our air and ground defenders' shooting sharp is the job of the Firebee, America's new high-performance pilotless jet plane. A product of Ryan Aeronautical Company's advanced aeronautical engineering, the Firebee was developed as a joint project of the U. S. Air Force, Army and Navy. It is now being manufactured for use by all three services.

The Firebee carries no human pilot, yet this remote-controlled target plane has phenomenal performance like a modern fighter. It is launched either from the ground or from a "mother" plane and is recoverable by a highly efficient parachute system that lowers it gently to the ground.

Design and development of the Firebee demanded the highest level of scientific talent and technical ability—in the aerodynamic, structural, mechanical, metallurgical and electronics fields. In this latest proud accomplishment, Ryan drew on rich experience gained through its 31 years in the forefront of aeronautical progress.

Because Ryan is *specialized, ingenious* and *versatile* . . . because it is an integrated company with superior abilities in many specialized fields, Ryan is better prepared to accomplish the unique, difficult technical engineering and production assignments of today's high-speed air age.



RYAN

★ SPECIALIZED
★ INGENIOUS
★ VERSATILE

Advanced-type Aircraft and Components
Jet and Rocket Engines and Components
Exhaust Systems for Aircraft
Electronics Equipment
Ceramics for "Hot Parts"
Weapons Systems Design and Management
Aircraft and Power Plant Research
Metallurgical Engineering
Thin-Wall Ducting
Firebee Pilotless Jet Planes

Pioneers in Each ★ Leaders in All

RYAN AERONAUTICAL COMPANY • Factory and Home Offices, Lindbergh Field, San Diego 12, Calif.
OTHER OFFICES: WASHINGTON, D. C.; DAYTON, OHIO; SEATTLE, WASHINGTON; NEW YORK CITY

All-Stainless . . . except for a few aluminum alloy small parts . . . this aircraft engine nacelle barrel is the newly designed unit being fabricated of Type 301 chromium-nickel stainless steel by Solar Aircraft Company, San Diego, Calif.

How Airframe Manufacturers Improve Structural Strength of Nacelles . . . with Type 301 Stainless

HERE IS ONE OF THE FIRST all-stainless steel nacelle barrels . . .

Type 301 is used because this "17-7" chromium-nickel stainless steel (Spec. AN-QQ-S-772, Type 2) provides superior mechanical properties that withstand stresses imposed by powerful engines often operating under adverse conditions.

Cold-rolled stainless of this type, quarter to full hard, in .012" to .050" thicknesses, provides minimum tensile strengths that range from 125,000 to 185,000 p.s.i. By its use, the required strength to meet specifications may be obtained without increase in weight . . .

For the stainless steel unit...semi-monocoque in design, with box-type longerons for engine mounts . . . weighs only 300 pounds, yet supports a 3500-pound engine.

This is only one of many applications in which advantage may be taken of the useful properties of chromium-nickel stainless steels. Trim bulk and deadweight by specifying correct types of stainless. They are strong, tough, and resist wear and abrasion.

Leading steel companies produce austenitic chromium-nickel stainless steels in all commercial forms. A list of sources of supply will be furnished on request.

INCO

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

LANDS WITH A 12-TON LOAD ...ON AN 855 FOOT STRIP!

No cargo airplane ever built can get into and out of the tight spots with a big bulk load, like the combat-proven Fairchild "Flying Boxcar." The C-119 lands and brakes to a stop on an 855 foot runway with a 12-ton load! Designed in every detail as a general military bulk cargo transport, the C-119 is equipped with reversible propellers and a powerful main and nose wheel braking system that enable it to land on the aircraft equivalent of the proverbial "dime." Here is the medium transport cargo airplane that so exactly meets the combat-transport needs of the U. S. Armed Forces!

ENGINE AND AIRPLANE CORPORATION
FAIRCHILD
Aircraft Division
HAGERSTOWN, MARYLAND

Guided Missiles Division, Wyandanch, L. I., N. Y.
Engine Division, Farmingdale, L. I., N. Y.

Advertisers

Glenn L. Martin Company, The.....189, 308
McCulloch Motors Corporation, Rhodes Lewis Company Subsidiary 150
★Meletron Corporation..... 226
Midwest Research Institute..... 285
Minneapolis-Honeywell Regulator Company..Back Cover

N

National Forge and Ordnance Company..... 24
★New York Air Brake Company, The, Watertown Division..... 243
North American Aviation, Inc. 229, 285
Northrop Aircraft, Inc..... 231

P

Pacific Division, Bendix Aviation Corporation 237
Pacific Scientific Company..... 10
Parker Appliance Company, The, Engine Accessories Division 274, 275
Pastushin Aviation Corporation..... 192
★Pesco Products Division, Borg-Warner Corporation.. 153
Piasecki Helicopter Corporation..... 210
Pittsburgh Plate Glass Company..... 279
PSP Engineering Company..... 146

R

Republic Aviation Corporation..... 239
Rhodes Lewis Company, Subsidiary of McCulloch Motors Corporation 150
★Rohr Aircraft Corporation..... 318
★Ryan Aeronautical Company..... 30

S

Sanborn Company, Industrial Division..... 29
Sandia Corporation..... 290
★Scintilla Magneto Division, Bendix Aviation Corporation..... 251, 301
Sikorsky Aircraft Division, United Aircraft Corporation..... 307
Skydyne Inc..... 313
Smith-Morris Corporation..... 139
★Southwest Products Company..... 301
The Sperry Corporation
Ford Instrument Company..... 14
★Sperry Gyroscope Company..... 13
★Vickers Incorporated..... 241
★Standard Coil Products Company, Inc., Kollsman Instrument Corporation Subsidiary 206
★Standard Pressed Steel Company, Aircraft Products Division..... 197
Standard-Thomson Corporation..... 235
Clifford Manufacturing Company Division..... 173
★Stewart-Warner Corporation, South Wind Division... 20
★Stratos Division, Fairchild Engine and Airplane Corporation..... 177
Stroukoff Aircraft Corporation..... 254
P. A. Sturtevant Company.....279, 300
Summers Gyroscope Company..... 183
Surface Combustion Corporation, Aircraft-Automotive Division.....218, 219
Sverdrup & Parcel, Inc..... 308

T

Taller & Cooper, Inc..... 281
Telecomputing Corporation..... 257
H. I. Thompson Fiber Glass Company..... 147

U

United Aircraft Corporation
Sikorsky Aircraft Division..... 307
Chance Vought Aircraft Division..... 285
United Manufacturing Company..... 255
United States Aviation Underwriters, Inc..... 12
United States Electrical Motors Inc., Aircraft Division 211
★United States Steel Corporation, American Steel & Wire Division, Columbia-Geneva Steel Division, Tennessee Coal & Iron Division, U.S. Steel Export Company Division..... 149

V

Varflex Corporation..... 21
★Vickers Incorporated, Division of The Sperry Corporation..... 241
Chance Vought Aircraft Division, United Aircraft Corporation..... 285

W

Waldes Kohinoor, Inc..... 11
Waterman Products Company, Inc..... 279
★Watertown Division, The New York Air Brake Company..... 243
Weber Aircraft Corporation, Subsidiary of Weber Showcase & Fixture Company, Inc..... 166
★Western Gear Works..... 179
Westinghouse Electric Corporation.....16, 17
Aviation Gas Turbine Division..... 265
★Weston Electrical Instrument Corporation..... 9
★Wittek Manufacturing Company..... 171
Wyman-Gordon Company..... 2

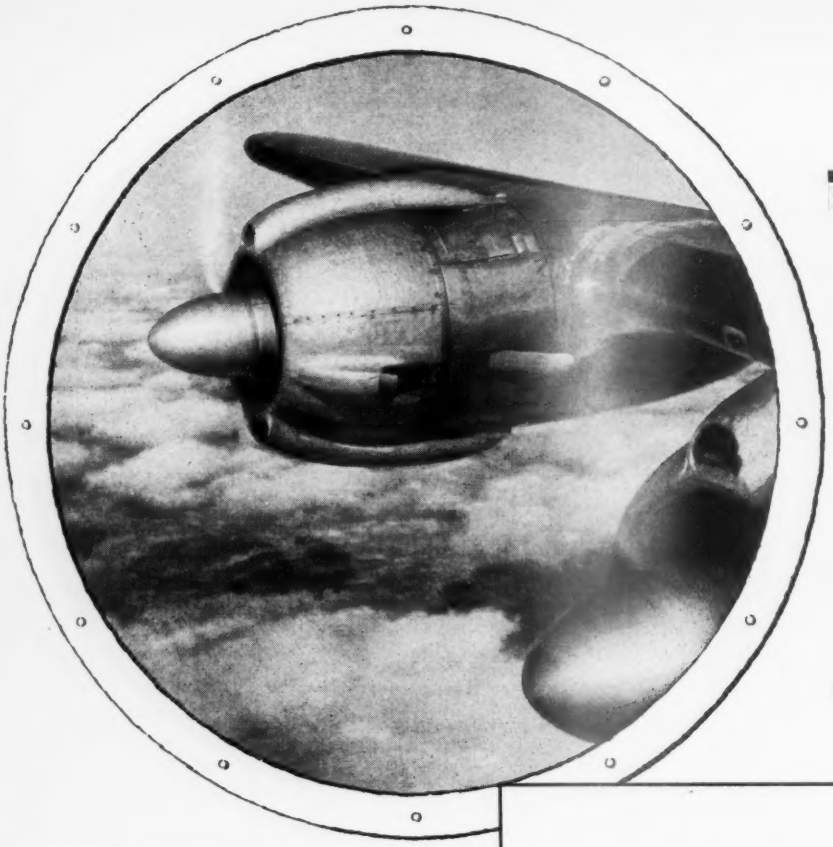
★ *Specifications and further information on the aircraft products of these companies will be found in the* **1953 AERONAUTICAL ENGINEERING CATALOG**

The only publication of its kind devoted exclusively to the aircraft industry, this CATALOG serves as a valuable buyers' and reference guide to sources and specifications on aircraft materials, parts, and accessories. It is distributed annually to Chief Engineers, Designers, Production Heads, and Purchasing Departments of all leading Aircraft, Aircraft Engine, Instrument, Accessory, and Aircraft Parts Manufacturers; Air Transport Companies; Army, Navy, and Governmental Agencies; Research Organizations; Engineering Libraries; etc.

Published Annually by

INSTITUTE OF THE AERONAUTICAL SCIENCES

2 East 64th Street New York 21, N.Y.



TIME FLIES

–do you?

Time is always flying. You can save some of your time by flying, too. Yes, ride the airlines regularly. You'll save moments, minutes, days, weeks to use as you choose—for business or pleasure. Next time... save time...*your* time. Fly!

You're looking out the window of a TWA Constellation at the Rohr-built "power packages" on the wing. For the Lockheed Constellation and other great airplanes, Rohr manufactures and assembles the engine mount, cowl panels, ducts, exhaust system, tanks, and other units which transform a Wright engine into a complete, ready-to-install "power package."

power packages by

ROHR

WORLD'S LARGEST PRODUCER OF READY-TO-INSTALL POWER PACKAGES FOR AIRPLANES

ROHR
AIRCRAFT CORPORATION
CHULA VISTA AND RIVERSIDE CALIFORNIA

AERONAUTICAL REVIEWS

New Products and Product Literature of interest to IAS members

▼▼▼▼

AIRCRAFT MATERIALS & PROCESSES

Ferro-Beryllium Master Alloy. Contributes to the hardenability of stainless steel. **The Beryllium Corp., Reading, Pa.**

Self-Lubricating Bearing Material. A metal locked together with specially formulated lubricative pigments. **Booker-Cooper, Inc., 8487 Melrose Pl., Los Angeles 46, Calif.**

Campco S-300, Rigid Plastic Sheet. Descriptive booklet. **Campco Div., Chicago Molded Products Corp., 2717 N. Normandy Ave., Chicago 35, Ill.**

"Silicone" Rubber Stocks. Known as Silastic "50" and "80," both have high tensile, elongation, and compression set characteristics. **Dow Corning Corp., Midland, Mich.**

Rod Selector Chart. To assist in the selection of a proper welding alloy. **Dept. P, Eutectic Welding Alloys Corp., 172nd St. & Northern Blvd., Flushing 58, N.Y.**

Straight-Wall Stainless Steel Tubing. For high-pressure and high-temperature applications. **Flexonics Corp., 1309 S. Third Ave., Maywood, Ill.**

"Alnico" Permanent Magnets. Six-page technical report No. PM-111. **Carboloy Dept., General Electric Co., Detroit 32, Mich.**

Custom Glass Parts. Eight-page descriptive catalog. **The Lancaster Lens Co., Lancaster, Ohio**

Foamed-in-Place Plastics. Twenty-eight-page descriptive booklet. **Lockfoam Div., Nopco Chemical Co., Harrison 24, N.J.**

All Temp Grease. Lubricates vehicle bearings in ambient temperatures ranging from −65°F. to +125°F. **The Texas Co., 135 E. 42nd St., N.Y.**

AIRCRAFT PARTS & EQUIPMENT

Thermocouple Probe. For the sensing of exhaust-gas temperatures in jet and rocket engines. **Aero Research Instrument Co., 1901 N. Hermitage Ave., Chicago 22, Ill.**

Flareless Tube Fitting. Suitable for either heavy- or thin-wall tubing. **The Aircraft Fitting Co., 1400 E. 30th St., Cleveland, Ohio**

Lightweight Gas-Turbine Auxiliary Power Units. Two models develop 170 and 120 hp., respectively. **AiResearch Manufacturing Co., 9851 Sepulveda Blvd., Los Angeles 45, Calif.**

"Conax Change-Under-Pressure Gland." Permits changing exposed wire thermocouples without reducing pressure on the system. **Conax Corp., 4515 Main St., Buffalo 21, N.Y.**

"Midlock" Tube Fitting. Designed for locking and sealing at any location on a tube. **Conax Corp., 4515 Main St., Buffalo 21, N.Y.**

Thermal Sensing Unit. For use wherever temperature limit indication is required. **Control Products, Inc., 300 Sussex St., Harrison, N.J.**

Carbon-Pile Regulator and Mount. For use in d.c. aircraft generator systems. Bulletin GEC-874. **General Electric Co., Schenectady 5, N.Y.**

Stock Gears, Speed Reducers, and Special Gears. 176-page descriptive catalog. **Grant Gear Works, Inc., 154 W. Second St., Boston 27, Mass.**

USE THESE TEAR-OUT POSTALS TO REQUEST ADDITIONAL INFORMATION DIRECT FROM THE MANUFACTURER

Aeronautical Engineering REVIEW

REQUEST FOR PRODUCT INFORMATION

An Official Publication INSTITUTE OF THE AERONAUTICAL SCIENCES (Aviation's Professional Engineering Society)

Please send information on the following item mentioned in the _____ Issue of AERONAUTICAL ENGINEERING REVIEW

NAME ..... POSITION .....

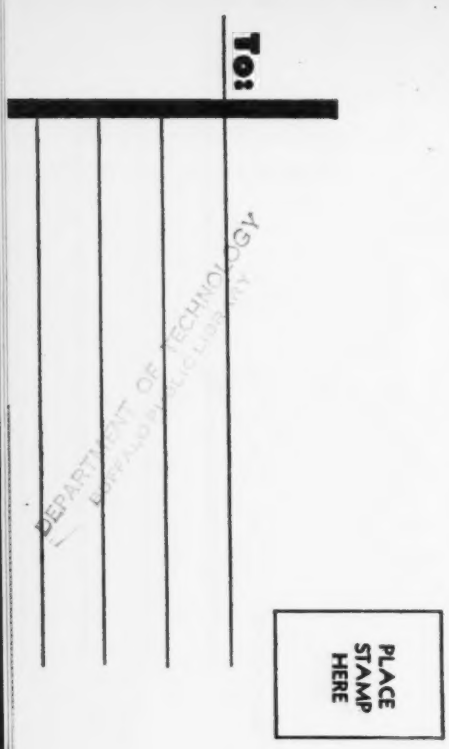
COMPANY .....

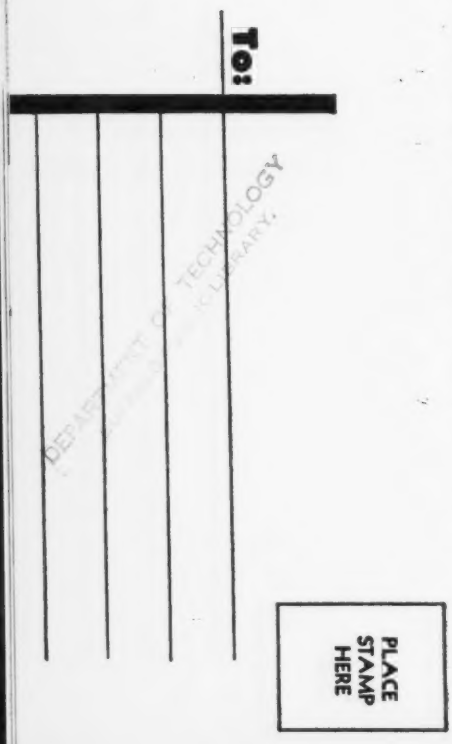
STREET .....

CITY & STATE .....

2 E. 64th St., New York 21, N.Y.

DEPARTMENT OF TECHNOLOGY PUBLIC LIBRARY BUFFALO





Cargo Tie-Down Buckles & Clasps. Descriptive brochure. **Harley Buckle Div., 50 Broadway, New York 4, N.Y.**

Push-Button Switches. Series W100 for use in machine gun and trim tab controls and canopy, bomb, and autopilot release mechanisms. **Hetherington, Inc., Sharon Hill, Pa.**

1½ In. Illuminated Panel Meters. Self-illuminated miniature meters for aircraft and electronic installations. **International Instruments, Inc., P.O. Box 2954, New Haven 15, Conn.**

Rotary Actuator. Provides rotary output up to 15 watts at speeds from 16 to 195 r.p.m. **Lear, Inc., Grand Rapids Div., 110 Ionia Ave., N.W., Grand Rapids 2, Mich.**

Miniature Ball Bearings. Twenty-page descriptive catalog. **Miniature Precision Bearings, Inc., Keene, N.H.**

Shielded Miniature Bearings. Single- and double-shielded miniature fractional-inch size of both full-race and retainer-type construction. **Miniature Precision Bearings, Inc., Keene, N.H.**

Magnetic Shut-Off Valve. Type VG4000A, for controlling the flow of noncorrosive gases or liquids. **Minneapolis-Honeywell Regulator Co., Aeronautical Div., 2600 Ridgway Rd., Minneapolis 13, Minn.**

Pressurized Aircraft Controls. Fifteen-page descriptive catalog. **Pacific Airmotive Corp., 2940 N. Hollywood Way, Burbank, Calif.**

Solenoid for Wide Temperature Variations. Supplies actuating force at ambient temperatures from −65°F. to +500°F. **PSP Engineering Co., South Gate, Calif.**

Check Valve. Features low-pressure drop. Bulletin No. 1053. **Republic Mfg. Co., 1930 W. 77th St., Cleveland 2, Ohio**

High-Pressure D.C.-Driven Air Compressor. Provides a complete, self-contained air source for aircraft pneumatic systems. **Rhodes Lewis Co., 6101 W. Century Blvd., Los Angeles 45, Calif.**

Fundamental Operating Theory of High-Tension and Low-Tension Ignition Systems. Sixty-two-page descriptive book entitled *The Aircraft Magneto.* **Scintilla Magneto Div., Bendix Aviation Corp., Sidney, N.Y.**

Heavy Duty Cowling & Access Latches. Descriptive design portfolio. **Simmonds Aerocessories, Inc., Tarrytown, N.Y.**

Dryseal-Thread Pressure Plugs. Descriptive bulletin. **Standard Pressed Steel Co., Box No. 869, Jenkintown, Pa.**

Dual Drive Adapter. For use with flexible shaft drives where multiple units are driven from the same power source. **F. W. Stewart Mfg. Corp., 4311 Ravenswood Ave., Chicago 13, Ill.**

Airplane Exit Lighting System. Features an independent power source and automatic impact switch. **B. K. Sweeney Mfg. Co., 1601 23rd St., Denver 17, Colo.**

Gear Racks. Descriptive folder. **Worcester Gear Works Inc., Dept. 72, 18 Grafton St., Worcester 8, Mass.**

ELECTRONIC & ELECTRICAL EQUIPMENT

Metalized-Ceramic Feed-Through Insulators. Features brazing and service temperatures up to 1,400°F. **Advanced Vacuum Products, 22 Liberty St., Stamford, Conn.**

Taper Technique for Miniature Electrical Connections. Eliminates terminal screws or soldering in electrical circuits. **Aircraft-Marine Products, Inc., Electronics Div., 2100 Paxton St., Harrisburg, Pa.**

Standard Short Slot Hybrids & Accessories. Engineering report RR 585. **Airtron, Inc., Linden, N.J.**

Q Meter Type 260-A. Has a frequency coverage of 50 kc. to 50 mc. **Boonton Radio Corp., Boonton, N.J.**

Microsyn Position Indicator. An electromechanical signal generator that transforms angular displacement into an electrical signal for measurement of any mechanical variable. Bulletin M. **Doelcam Corp., Soldiers Field Rd., Boston 35, Mass.**

Hermetically Sealed Terminals. Descriptive bulletin No. 949-A. **Electrical Industries Div., Amperex Electronic Corp., 44 Summer Ave., Newark 4, N.J.**

Transistor Closures. Features a soldering dimple and hole to permit easy sealing. **Electrical Industries, Inc., 44 Summer Ave., Newark 4, N. J.**

Thermistor Applications. Descriptive technical data sheets No. TH-9, 10, 11, and PM-116. **General Electric Co., Carboloy Dept., Detroit 32, Mich.**

Electric Heating Elements and Units. Twenty-nine-page descriptive catalog. **Heatube Corp., 612 Grand St., Allegan, Mich.**

Hermetically Sealed Resistors. Capable of withstanding severe exposure to moisture and salt spray. **Instrument Resistors Co., Union, N.J.**

Magnetic Amplifier Regulated Power Supply. Unit MR532-15, is rated at 5–32 volts d.c. at 15 amps. and has a regulation accuracy of ±1 per cent. **Perkin Engineering Corp., 345 Kansas St., El Segundo, Calif.**

Electric Motor Brush-Holders. Twenty-one-page descriptive catalog No. 53-B. **Phoenix Electric Mfg. Co., 711 W. Lake St., Chicago 6, Ill.**

Full-Wave High-Vacuum Rectifier Tube. JAN 6106, employs a cathode-type structure with extruded ceramic heater insulator and a coil-type heater instead of a filament structure. **Red Bank Div., Bendix Aviation Corp., Eatontown, N.J.**

Fixed Wirewound Power Resistor. The windings of the "Castohm" resistors are imbedded in a special ceramic that forms an integral coating and core. Bulletin L-29. **Shallcross Mfg. Co., Collingdale, Pa.**

Heavy-Duty Feed-Through Capacitor. For use in suppressing r-f interference. Bulletin No. 216. **Sprague Electric Co., 339 Marshall St., North Adams, Mass.**

Phase Shifting Instrument. Alters phase of an input sinusoid without disturbing amplitude or wave form of the signal. **Technology Instrument Corp., Acton, Mass.**

6–60 CM Wavemeter. Model WIN6AA, a compact survey-type wavemeter with very wide range. **Thompson Products, Inc., Electronics Div. 2196 Clarkwood Rd., Cleveland 3, Ohio**

PRODUCTION & MAINTENANCE EQUIPMENT

Hydraulic Press. For molding of rubber and plastic parts. **Atlas Hydraulics Inc., 3576 Ruth St., Philadelphia 34, Pa.**

Model 12 Sterilshield. Dust- and germ-proof cabinets for exacting instrument assembly. **The Baker Co., Inc., Maplewood, Me.**

Maag Bevel Gear Grinder. Holds spacing between teeth and tooth form accurate to within two ten thousandths of an inch. **Hall-Scott Motor Div., ACF-Brill Motors Co., 2850 Seventh St., Berkeley 10, Calif.**

Pneumatic Impact Press. Model 3-VS. Six-page descriptive folder. **Heidrich-Nourse Co., 631 E. Third St., Los Angeles 13, Calif.**

Electronic Induction Heating Generator. For brazing, soldering, hardening, annealing, and melting. **Induction Heating Corp., 181 Wythe Ave., Brooklyn 11, N.Y.**

Aluminum Heat-Treat Furnace. Descriptive brochure. **J. S. Macaulay, James H. Knapp Co., 1731 Workman St., Los Angeles 31, Calif.**

Horizontal Extrusion Presses. Eight-page bulletin. **Lake Erie Engineering Corp., Box 68, Kenmore Sta., Buffalo 17, N.Y.**

Stretch Forming Press. To produce compound curves on magnesium skins. **R. A. Lalli Co., 267 Madison Terrace, Bridgeport, Conn.**

Steel Beam Trammels. Series 180 for layout work, scribing, and measuring. **The Lufkin Rule Co., Saginaw, Mich.**

High-Production Hobber Machine. Provides quick change-over to handle a variety of parts. **Michigan Tool Co., Detroit, Mich.**

"Fifty-Eight Ideas for Cutting Costs with 'Scotch' Brand Pressure-Sensitive Tapes." Thirty-six-page report to the aircraft industry. **Minnesota Mining & Mfg. Co., 900 Fauquier St., St. Paul 6, Minn.**

High-Temperature Masking Tape. No. 214, for masking treated metals in oven temperatures up to 325°F. **Minnesota Mining and Mfg. Co., 900 Fauquier St., St. Paul 6, Minn.**

Desk or Pocket Drafting Device. Combines the functions of T-Square, triangles, straight-edge, scales, and protractor in one unit. **Pickett & Eckel, Inc., 5 S. Wabash Ave., Chicago, Ill.**

Automatic Torque Wrench. Designed to tighten nuts, bolts, and screws to exact predetermined tension, without the need for warning signals. **Reasor Manufacturing Co., St. Charles, Ill.**

"Glide-Rule." Portable drawing instrument combines various engineer's drafting tools. **Smith Drake Corp., 1206 S. La Brea Ave., Inglewood, Calif.**

USE THESE TEAR-OUT POSTALS TO REQUEST ADDITIONAL INFORMATION DIRECT FROM THE MANUFACTURER

Aeronautical Engineering Review

REQUEST FOR PRODUCT INFORMATION

An Official Publication
INSTITUTE OF THE AERONAUTICAL SCIENCES
(Aviation's Professional Engineering Society)
2 E. 64th St., New York 21, N.Y.

Please send information on the following item mentioned in the _____ Issue of AERONAUTICAL ENGINEERING REVIEW

NAME ..... POSITION .....

COMPANY .....

STREET .....

CITY & STATE .....

DEPARTMENT OF PUBLIC LIBRARY TECHNOLOGY

Aeronautical Engineering Review

REQUEST FOR PRODUCT INFORMATION

An Official Publication
INSTITUTE OF THE AERONAUTICAL SCIENCES
(Aviation's Professional Engineering Society)
2 E. 64th St., New York 21, N.Y.

Please send information on the following item mentioned in the _____ Issue of AERONAUTICAL ENGINEERING REVIEW

NAME ..... POSITION .....

COMPANY .....

STREET .....

CITY & STATE .....

To:

PLACE STAMP HERE

To:

PLACE STAMP HERE

RESEARCH & TEST EQUIPMENT

High-Frequency Pressure Cells. SR-4 Type HF, consists of a pressure sensitive tube on the outside of which are bonded special SR-4 strain gages. Bulletin No. 4107. **Baldwin-Lima-Hamilton Corp., Philadelphia 42, Pa.**

Load Cells. Type Baldwin SR-4, for measuring forces and weights. **Baldwin-Lima-Hamilton Corp., Philadelphia 42, Pa.**

Vibration-Measuring Instrument. "Askania" Hand Vibrograph, measures longitudinal, torsional, and pressure vibrations. **Epic Inc., 154 Nassau St., New York 38, N.Y.**

Frequency Meters. For field and laboratory use. **Frequency Standards, P.O. Box 504, Asbury Park, N.J.**

Instrument Standardization Unit. For instrument calibration. **General Electric Co., 1 River Rd., Schenectady 5, N.Y.**

"Glennite" Accelerometer. For high-impact shock measurements. Bulletin A105. **Gulton Mfg. Corp., Metuchen, N.J.**

"Andrex" X-Ray Equipment. For inspection of internal structural members of airplanes. **Holger Andreasen, Inc., 703 Market St., San Francisco, Calif.**

X-Y Plotter & Recorder. A two-coordinate portable recording instrument for continuous curve or discrete point plotting. **Librascope, Inc., 1607 Flower St., Glendale, Calif.**

Shock-Resistant Galvanometer. Permits oscillograph recording during shock and vibration conditions. **Midwestern Geophysical Laboratory, 3401 S. Harvard, Tulsa, Okla.**

Model 557 Oscillograph. Features 14 channels of separate data. **Midwestern Geophysical Laboratory, 3401 S. Harvard, Tulsa, Okla.**

"Autograf" Automatic Curve Follower. A portable two-axis graphic recording instrument. **Francis L. Moseley Co., 409 N. Fair Oaks Ave., Pasadena 3, Calif.**

Oxygen Regulator Test Stand. Model OTS-562, tests aircraft diluter-demand oxygen regulators. **National Instrument Laboratories, Inc., 6108 Rhode Island Ave., Riverdale, Md.**

Brinnell Microscope-Reader. Used with a Brinnell-type metal hardness testing machine for checking ferrous and nonferrous metals. **Pacific Transducer Corp., 11921 W. Pico Blvd., Los Angeles 64, Calif.**

Static Test Stand. For testing strength of jettisonable fuel tanks and other external stores components. **Pastushin Aviation Corp., 6901 Melrose Ave., Los Angeles 38, Calif.**

GAP/R Electronic Analog Computing Devices. Descriptive catalog. **George A. Philbrick Researches, Inc., 230 Congress St., Boston 10, Mass.**

High-Speed, Six-Digit Decade-Scaler. For frequency and nuclear measurements in computers. **Research & Controls Instruments Div., North American Philips Co., 750 S. Fulton Ave., Mount Vernon, N.Y.**

Ultrasonic Nondestructive Testing Equipment. Eight-page descriptive brochure No. 50-110. **Sperry Products, Inc., Danbury, Conn.**

Pulse-Forming Networks. For use in testing various types of hydrogen thyratron tubes. **Sprague Electric Co., 339 Marshall St., North Adams, Mass.**

Equipment and Sources for Gamma Radiography. Descriptive catalog. **Technical Operations, Inc., 6 Schouler Court, Arlington 74, Mass.**

Complex Plane Analyzer. Type 250-A, for network analysis and control system design. **Technology Instrument Corp., Main St., Acton, Mass.**

Audiosweep Generator. Permits point-by-point plotting of frequency response curves. **Technomatic Instrument Co., 2316 Pico Blvd., Santa Monica, Calif.**

"Blak-Ray" (Blacklight) Lamp. For inspection and flaw detection. **Ultra-Violet Products, Inc., South Pasadena, Calif.**

Accessories for Indicating, Controlling, and Recording Instruments. Forty-two-page Catalog TC-10, describes thermocouples, radiation detectors, resistance bulbs, and other accessories. **Wheelco Instruments Div., Barber-Colman Co., Rockford, Ill.**

Insulation Resistance Test Set. For maintenance of medium- and high-voltage electrical equipment. **The Winslow Co., 9 Liberty St., Newark, N.J.**

Convair speeds you on your way

...*after the flight, too!*

If you're the kind of air traveler who likes *convenience* with speed and luxury . . . then welcome aboard the Convair.

From nimble takeoff to sure-footed landing, the Convair is a model of engineering efficiency. And its exclusive hand-baggage racks and self-contained stairway speed you on your way *after* the flight, too! No more baggage claiming lines. Often you'll save 30 minutes or more on arrival.

Ask your favorite airline or travel agent to make your next flight a Convair . . . the world's most popular passenger plane, with built-in *get-up-and-go!*

As a transport-trainer for the U.S. Air Force, the Convair is setting new records for versatility and performance . . . another evidence of Convair's **Engineering to the Nth Power**

CONVAIR

SAN DIEGO AND POMONA, CALIFORNIA
FORT WORTH AND DAINGERFIELD, TEXAS

MORE AIRLINES HAVE CHOSEN CONVAIR THAN ANY OTHER MODERN PASSENGER PLANE: ***Now flying:*** Aerolineas Argentinas • Aero O/Y, *Finland* • Alitalia, *Italy* • American • Braniff • Canadian Pacific • Continental • Delta-C & S • Ethiopian • Hawaiian • KLM Royal Dutch • Linee Aeree Italiane, *Italy* • National • Northeast • Orient, *Pakistan* • PAL, *Philippine* • Pan American • Republic of Indonesia • Sabena, *Belgium* • Swissair, *Switzerland* • Trans-Australia • United • Western — ***Soon to fly:*** Aeronaves De Mexico • Avensa, *Venezuela* • CMA, *Mexico* • Cruzeiro do Sul, *Brazil* • JAT, *Jugoslavia* • Lufthansa, *Germany* • Real S. A., *Brazil*

How to make your shots count

A lot of work has been done by a lot of people to increase aircraft stability. And now, from Honeywell, there comes a device that greatly advances the cause of the more stable flying gun platform, so important to accurate rocket and gun firing.

This device is called a Turn Coordinating Yaw Damper. It is now in production and is currently being installed in the AVRO CF-100. That's the all-Canadian fighter, pictured above, guarding the northern approaches to our continent.

The new Turn Coordinating Yaw Damper is a significant advance over earlier Yaw Dampers. With it a pilot can fly with his feet off the rudder pedals. No matter how he moves the stick, the turn—whether transient or steady—will always be coordinated. He is relieved of his concern over yaw, and has more positive assurance that his shots will count.

On the CF-100 the Turn Coordinating Yaw Damper is made to function as the rudder axis for the Honeywell MH-11 Autopilot, with which the CF-100 is also equipped.

The important improvement in performance made possible by the Turn Coordinating Yaw Damper serves to demonstrate how *automatic control* is such an important part of aviation progress. And *automatic control* is Honeywell's business.

MINNEAPOLIS
Honeywell

H HONEYWELL *Aeronautical Controls*

2600 Ridgway Road, Minneapolis 13, Minn.

DEC